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16. ABSTRACT

Field studies were conducted in two southern Idaho areas to determine the effects of different management practices on the quality and quantity of the runoff from surface-irrigated fields. Pollutant removal systems (primarily mini-basins, vegetated buffer strips and sediment retention ponds) were installed at some of the study sites and evaluated to determine their effectiveness in removing sediment and other materials from return flows. The results indicate that water, sediment and nutrient losses from surface-irrigated areas can be greatly reduced or eliminated by the use of certain types of management practices and/or pollutant removal systems.

Linear programming models were used to determine the economic impacts of using different types of practices to control surface runoff and sediment losses from model farms. The results indicate that sediment losses from surface-irrigated fields can be reduced by as much as 50 percent at modest cost. Elimination of surface runoff and sediment losses would require the use of sprinkler irrigation systems and would decrease net income by about 15 percent.

Some of the overall impacts of pollutant losses from surface-irrigated areas were evaluated. The annual cost of removing sediment from canals and ditches in the Boise Valley was found to be about $20 per hectare. Irrigation return flows contribute to water quality problems in the Boise River and downstream in the Snake River.

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by

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FOREWORD

The Environmental Protection Agency was established to coordinate administration of the major Federal programs designed to protect the quality of our environment.

An important part of the Agency's effort involves the search for information about environmental problems, management techniques and new technologies through which optimum use of the Nation's land and water resources can be assured and the threat pollution poses to the welfare of the American people can be minimized.

EPA's Office of Research and Development conducts this search through a nationwide network of research facilities.

As one of these facilities, the Robert S. Kerr Environmental Research Laboratory is responsible for the management of programs to: (a) investigate the nature, transport, fate and management of pollutants in groundwater; (b) develop and demonstrate methods for treating wastewaters with soil and other natural systems; (c) develop and demonstrate pollution control technologies for irrigation return flows; (d) develop and demonstrate pollution control technologies for animal production wastes; (e) develop and demonstrate technologies to prevent, control or abate pollution from the petroleum refining and petrochemical industries; and (f) develop and demonstrate technologies to manage pollution resulting from combinations of industrial wastewaters or industrial/municipal wastewaters.

This report contributes to the knowledge essential if the EPA is to meet the requirements of environmental laws that it establish and enforce pollution control standards which are reasonable, cost effective and provide adequate protection for the American public.

William C. Galegar

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ABSTRACT

The primary objective of this study was to determine the effectiveness and cost impacts of different measures for controlling sediment and nutrient losses from surface-irrigated areas. On-farm management practices and pollutant removal systems were emphasized.

Sites in the Boise and Magic Valley areas of southern Idaho were instrumented and monitored so that the effects of different irrigation, cropping and tillage practices on the quality and quantity of surface runoff from these sites could be determined. In addition, sediment removal devices were installed at several of the sites and evaluted to determine their effectiveness in removing sediment, phosphorus and other materials from surface return flows. Devices evaluated included mini-basins, vegetated buffer strips, small on-farm sediment retention ponds and large district-type ponds. The results of the field investigations show that water, sediment and nutrient losses from surface-irrigated fields can be greatly reduced or even eliminated by the use of proper management practices and/or sediment retention systems.

Information relative to current crop production, tillage and irrigation practices, cost of production and income from crop production was collected from 150 farmers in the two study areas. This information was used to develop representative farm models for the areas. Estimates of the cost effectiveness of selected methods for reducing sediment losses from the farms were developed using linear programming models. Farm income consequences of having to meet specified restrictions on sediment losses were also determined. The results show that sediment losses from surface-irrigated fields can be reduced by as much as 50 percent at modest cost. Elimination of surface runoff and sediment losses would require the use of sprinkler irrigation which would decrease the returns to land and management by about 15 percent.

The overall impacts of pollutant losses from irrigated lands in the Boise Valley study area were evaluated. Sediment losses resulted in annual costs of about $1.4 million to keep canals and ditches clean in a 68,000-hectare irrigated area in the Valley. Water quality in the Boise River was found to be affected by irrigation activities in the Valley. Boise River water also contributes to pollution problems downstream in the Snake River.

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SECTION 1

INTRODUCTION

The importance of irrigation in producing crops in arid and semi-arid regions of the world is well documented. This practice is particularly important to western areas of the United States where irrigation is required for the production of most crops. While beneficial in many respects, irrigation can have serious detrimental effects on water quality since irrigation return flows may contain dissolved salts, sediment, plant nutrients and other materials. The effects of these materials on the quality of receiving waters are a major concern in the western states since irrigation return flows constitute a large portion of the flow in many streams in this region.

Concerns about water quality have led to the passage of legislation (Federal Water Pollution Control Act Amendments of 1972) designed to alleviate water pollution problems. The U.S. Environmental Protection Agency is concerned with achieving the goals of this Act; and, as a result, has initiated comprehensive research, development and demonstration programs designed to effectively control pollutant discharges. Included are programs to upgrade the technology for controlling pollutant discharges from irrigated areas.

The major water quality problem in most western irrigated areas is increased salt concentrations in the return flows as a result of the pickup of minerals from soils and the loss of water through evapotranspiration (Wells, 1974). As a result, a number of studies have been conducted to find ways to reduce the buildup of salt in return flows in these areas. Salinity is not a major problem, however, in many irrigated areas. Instead, the major problem is sediment in the surface runoff from irrigated fields; and, to a lesser extent, nitrate and other nutrients in ground and surface waters in these areas.

There are a number of ways in which sediment and nutrient losses from irrigated areas can be effectively controlled. These include the use of irrigation and/or other practices which eliminate or reduce surface runoff and resulting pollutant losses from individual fields, on-the-farm removal of sediment and nutrients from surface return flows and removal after the return flow has entered surface drainage systems or streams. Relatively little is known,however, about the effectiveness and cost impact of specific control measures.

The purpose of this study was to further the development of the technology needed to effectively control sediment and other pollutant losses from surface-irrigated areas. Primary emphasis was placed on determining the effectiveness and cost impact of on-the-farm control measures and removal systems. The specific objectives were to:

1. Determine the effects of different water management, cropping, and tillage practices and other physical factors on the quality and quantity of surface runoff from irrigated fields.
2. Determine the effectiveness of pollutant removal devices and systems in controlling sediment and nutrient losses from irrigated areas.
3. Determine the cost effectiveness and aggregate effects of pollutant removal systems and discharge control measures.

SECTION 2

SUMMARY AND CONCLUSIONS

The results of field investigations conducted in the Boise and Magic Valley areas of southern Idaho show that water, sediment and nutrient losses from surface-irrigated fields are affected by a number of factors and that these losses can be effectively controlled. For example, the results indicate that sediment and nutrient losses from furrow-irrigated fields are directly related to furrow stream size and that it may be possible to completely eliminate these losses by using proper furrow stream sizes. At one of the study sites, reducing the furrow stream size by 47 percent actually resulted in net gains of sediment and phosphorus on the site.

Cutting furrow flows back after they reach the end of a field increases the efficiency of water use and reduces sediment loss. The use of cutback irrigation on a corn field increased the water-use efficiency from 41 to 78 percent and reduced sediment loss by 93 percent. A 72 percent reduction in the amount of surface runoff from a potato field resulted in an 87 percent decrease in the amount of sediment lost from this field. Phosphorus losses were also reduced by the use of cutback irrigation.

Preplant irrigation, tillage and cropping practices were found to affect surface runoff and resulting pollutant losses from furrow-irrigated fields. Irrigating in non-compacted furrows resulted in less runoff and sediment loss than irrigating in compacted furrows. However, high infiltration rates in the non-compacted furrows resulted in excessive deep percolation losses and poor water distribution efficiencies in these furrows. For corn, over one-third of the seasonal sediment loss occurred during a preplant irrigation. Wetting only the seedbed area of a bean field during the preplant irrigation resulted in less sediment loss than wetting the entire field surface. Reusing sediment-laden return flows from row crops to irrigate close-growing crops is an effective way to remove sediment from return flows. Reuse of return flows on an alfalfa field resulted in removal of 79 percent of the sediment in the flow entering the field.

Vegetated buffer strips can be used to retard the runoff from surface-irrigated fields and thereby cause sediment in the runoff to settle out. Sodded grass and barley strips installed at the lower end of a corn field were effective in removing about 45 percent of the sediment from the runoff passing through these strips. Extra plantings of spring wheat seeded across the lower end of a wheat field reduced the amount of sediment lost from this field by 79 percent.

Mini-basins which collect and detain the runoff from several adjacent furrows can remove up to 95 percent of the sediment from the runoff from a field. Evaluations of twelve mini-basins constructed on the lower end of a bean field showed that the basins reduced the seasonal sediment loss from the field from 14,950 kg/ha to 680 kg/ha. Basins with grassed overflow sections which collect the runoff from 4 or 5 furrows are recommended.

Properly sized on-farm sediment ponds will remove over 70 percent of the sediment from incoming runoff, and can be used for at least two years before they will require cleaning. Large sediment ponds which remove sediment from return flows in wasteways can be used as an alternative to controlling sediment losses at their source. The sediment removal efficiences of the large ponds evaluated in this study ranged from 40 to 70 percent.

The cost effectiveness of control practices considered in this study varied widely. In general, cutback irrigation is more expensive than the other methods of controlling sediment losses from surface-irrigated fields. On-farm sediment ponds will retain about two-thirds of the sediment loss from furrow-irrigated fields at a cost of less than two dollars per metric ton of sediment retained. Vegetated buffer strips compare favorably with sediment ponds on a cost effectiveness basis. Mini-basins retain more sediment than ponds or vegetated strips but are more expensive than ponds or strips in terms of their total cost and their cost per unit of sediment retained.

Converting a surface irrigation system to a side-roll sprinkler system to eliminate surface runoff and sediment losses from a farm would greatly increase the costs over those associated with other control practices. Potatoes are an exception since the amount of sediment loss from surface-irrigated potato fields is usually much greater than the loss from other surface-irrigated crops. For other row crops, sprinklers would cost about ten times as much per unit of sediment retained as would sediment ponds and about four times as much as mini-basins. On grain, sprinklers would cost about eighteen times as much as ponds and about six times as much as mini-basins.

The results of an analysis to determine the farm income consequences of having to meet specified restrictions on sediment losses show that the use of sediment ponds to meet these restrictions would reduce the returns to land and management by slightly more than one percent. The use of mini-basins would reduce the returns by a little more than 2.5 percent. The use of sprinklers, however, would reduce the returns by about 15 percent.

Some of the overall impacts of surface irrigation in the Boise Valley were considered in this study. The physical impacts of irrigation were found to focus about water quality and groundwater levels. During the irrigation season, specific conductivity levels and nitrogen and phosphorus concentrations in the Boise River at Notus (near the lower end of the Valley) are from five to ten times higher than they are at Boise (near the upper end of the Valley). High groundwater levels, which are primarily due to irrigation, prevent the use of some valley lands for certain purposes and make it necessary for some cities to run pumps the year around to reduce groundwater levels. Sediment losses resulted in annual costs of about $1.4 million to keep canals and ditches clean in a 68,000-hectare area in the Valley. Boise River water also contributes to pollution problems downstream in the Snake River.

SECTION 3

RECOMMENDATIONS

Efforts to disseminate the information now available relative to the control of sediment and nutrient losses from surface-irrigated lands should be intensified. Sediment and nutrient losses from many surface-irrigated areas could be greatly reduced at modest cost by the use of the control technology now available. Information relative to the cost effectiveness of different control practices should be included as an integral part of all education programs on irrigation return flow control.

Criteria for designing and operating different types of sediment retention systems need to be developed. On-farm systems such as vegetated buffer strips, mini-basins and sediment ponds have been shown to be effective in removing sediment and certain nutrients from surface return flows. Large district-type ponds are also effective in this regard. However, criteria for designing and operating these systems are quite limited at this time.

Work needs to be done to develop a relatively simple and easily used device for monitoring surface return flows. If such a device were available, it would enable irrigators to more easily determine the extent and seriousness of return flow losses from their land. This, in turn, would facilitate implementation of needed control measures.

Efforts to develop a better understanding of the effects of irrigation, cropping, tillage and other management practices as well as physical factors on sediment and nutrient losses from surface-irrigated lands should be continued. These efforts should include an assessment of the effects of changes in management practices to meet energy limitations on sediment and nutrient losses, and an assessment of the cost impacts of such changes. Particular attention should be given to the effects of reducing the number of tillage operations, better irrigation scheduling, limiting or changing the use of sprinkler systems and the use of irrigation methods which have low energy requirements.

Efforts should be made to improve the data base for estimating the costs and documenting the benefits of improving sediment and nutrient loss control practices. The possibility exists that higher crop yields and better crop quality may help offset the costs of improved management practices. More work needs to be done to establish the effects of improved irrigation water management and other management practices on crop yield and quality and to document resulting economic benefits. Accounts of the labor time, machine operating time and costs associated with the use of different management practices and devices to control losses should be kept.

Additional research is needed to more fully determine the overall impacts of controlling sediment and nutrient losses from surface-irrigated areas. Improvements in water quality as well as economic benefits occur both on the farm and downstream as a result of the implementation of effective control programs. As more detailed information relative to the effectiveness and costs of control programs becomes available, it will be possible to make better estimates of the overall impacts of these programs.

SECTION 4

BACKGROUND INFORMATION

National concerns about water quality problems have focused attention on the major sources of water pollutants. Agriculture has been accused of being a major source in many areas; and, as a result, considerable effort and resources have been devoted to determining agriculture's contribution to water quality problems. According to Viets (1970), the usual approach to the study of water quality problems in agricultural areas has been to assign certain inputs of pollutants to identifiable sources and to charge the rest by difference to agriculture. Possible agricultural inputs include animal wastes, eroded soil, nutrients washed from dead vegetation, leachate from septic tanks and fertilizer materials either in solution or adsorbed on sediment particles. Identifying the source of a particular pollutant found in water in an irrigated area is usually extremely difficult.

The purpose of this section of the report is to briefly summarize the findings of studies which have dealt with sediment and nutrient losses from agricultural lands. Information obtained from previous irrigation water quality investigations conducted in the two study areas is included.

GENERAL

Sediment has been described as a primary hazard to water quality (Viets, 1971). Robinson (1971) describes sediment as a pollutant which fills reservoirs, lakes and ponds; clogs stream channels; settles on productive land; and destroys aquatic habitats. It may also act as a scavenger or release nutrients. Nutrient losses from land, particularly phosphorus losses have been related to sediment losses through soil erosion. Several investigators (Scarseth and Chandler, 1938; Volk, 1945; and Ensminger and Cope, 1947) have found that most of the phosphorus added to soils is removed by soil erosion processes. The soil fraction most subject to detachment and transport by water has been shown to be higher in total phosphorus than the original soil (Neal, 1944; Stoltenberg and White, 1953). Stoltenberg and White also found that the amount of nitrogen in sediments was almost double the amount in surface soil.

Most of the sediment in irrigation return flows results from the irrigation of sloping lands by the furrow method. Where irrigation water is applied on level or nearly level land, erosion is usually light. Likewise, erosion does not usually occur with a properly designed sprinkler irrigation system since water is applied no faster than the soil will absorb it. However, when water is applied on sloping lands by the furrow method, erosion is a constant threat (Mech, 1959). Land slope, soil conditions, crop cover, furrow stream size and other factors influence the amount of erosion. As pointed out by

Tovey, et al., (1962), a slight change in one or more of these factors can significantly change the erosion rate. Methods for reducing erosion rates have been presented by Mech (1959) and Mech and Smith (1967). Guidelines for controlling the amount of sediment in irrigation return flows have been presented by Carter (1976) and Carter and Bondurant (1976).

Studies have been conducted in several areas to determine the concentrations and sources of nitrate and other nutrients in waters in these areas. In a study of tile drain effluents in the San Joaquin Valley, Johnston et al., (1965) found the highest concentrations of nitrogen in areas where heavy applications of nitrogen fertilizers were made. In another study conducted in this area, Stromberg (1966) indicates that not all of the nitrate in waters in the Central San Joaquin Valley can be charged to fertilization practices. Bower and Wilcox (1969) found that increasing the application of nitrogen fertilizer to three irrigated areas adjacent to the upper Rio Grande River did not increase nitrate concentrations in the river. In Nebraska, Muir et al., (1973) found that only at sites of intensive irrigation development and with irrigation of valley positions of shallow water table has fertilizer nitrogen contributed substantially to a reduction in groundwater quality. Return flow from a 203,000-acre tract of calcareous silt loam soils irrigated with water diverted from the Snake River in Southern Idaho increased the downstream total salt and nitrate-nitrogen loads, but decreased the downstream water-soluble phosphorus load (Carter et al., 1971).

General methods for improving the quality of irrigation return flows have been summarized by Law and Skogerboe (1972). These include improved on-the-farm methods of water application, tailwater recovery and reuse, judicious use of slow-release or other controlled fertilizers and certain specialized cultural practices.

On-the-farm methods of water application affect both the quality and quantity of irrigation return flows. Furrow irrigation is the most common method of application because of low installation cost, while sprinkler irrigation is used because of its adaptability to a wide range of field conditions. Two new methods which offer promise are subsurface application, and drip or trickle irrigation (Wells, 1974). All four systems must be accurately designed if efficient application and controlled distribution of water are to be obtained. If the systems are correctly designed and used, deep percolation and surface runoff losses are minimized and the need for control measures is reduced.

Tailwater recovery and reuse can be achieved by the use of pumpback systems similar to the one described by Bondurant (1969). Such systems catch surface runoff at the bottom of a field and pump it back to the head of the field or to other fields for reuse. Even though field erosion is not eliminated, sediment losses are prevented and the efficiency of water use is increased. Sediment retention systems used either separately or in conjunction with pumpback systems effectively remove much of the sediment from irrigation return flows. As pointed out by Robbins and Carter (1975), sediment ponds can be built in depressions or on shallow soil areas at minimum cost to a farmer if he uses his own equipment during slack work periods. The sediment can be used to improve the land's topography and value. Even so, trapping sediment in man-made ponds is generally regarded as a temporary or emergency solution for the sediment loss problem since this practice does not prevent erosion from occurring.

Costs are an important consideration in selecting alternatives for improving the quality of irrigation return flows. There must be an economic incentive for an irrigator to control irrigation return flow (Wells, 1974). Such an incentive may be either negative or positive. For example, a regulation restricting the quantity of sediment in return flows might force an irrigator to install on-farm settling basins without any apparent return, thereby becoming a negative economic incentive. However, if this same irrigator improves his practices in such a way that sediment and nutrient losses are decreased and crop yields are increased to the extent that the combined benefits are greater than additional costs, he has a positive economic incentive.

Conversion from gravity to sprinkler irrigation has been suggested as one means of reducing or eliminating irrigation return flows. The economic incentive to a farmer to convert must come from a marked increase in the economic efficiencies of his farming operation. This involves such factors as the size of the farm, types of crops grown, and prices of the inputs as well as the products grown on the farm.

Economic efficiencies were estimated through long-run cost curves for the Dry Lake area in the Boise Valley (Coffing and Lindeborg, 1966). Costs per unit of output decreased with increasing size of the farms indicating that for the larger farms there is an economic incentive to allocate the input factors, including irrigation water, to the highest economic use.

An economic study of how well irrigation water was used in four areas along the Snake River was also based on economic efficiences (Lindeborg, 1970). Prices of irrigation water were estimated. Since water has no free market, its price in growing crops was estimated by the value of the increase in output resulting from the final unit of water used in producing the output.

PREVIOUS INVESTIGATIONS IN THE STUDY AREAS

Several water quality studies have been conducted in irrigated areas in southern Idaho. Jensen et al., (1951) made a detailed study in 1947 and 1948 of the chemical characteristics of surface waters used for irrigation. Twenty-seven major water sources were systematically sampled and analyzed for dissolved salts over the two year period. Based on U.S. Department of Agriculture standards, all but one of these sources was classified as excellent in quality for irrigation usage.

A study of the quality of surface and drainage well waters in the Boise Valley was made by Lewis (1959). Sixty sites, including 50 drainage and domestic wells and 10 surface water sources, were periodically sampled during the 1958 irrigation season. The results of this study indicated that most of the water sources sampled were suitable for irrigation usage and that salinity is not a major problem in the Boise Valley.

In 1970, a study was started to determine the effects of irrigated agriculture on water quality in the Boise Valley. During the first phase of this study, surface and ground waters in gravity-irrigated areas in the Valley were systematically sampled and analyzed to determine the kinds and amounts of pollutants in these waters (Naylor et al., 1976). Seventy-nine sites, including 28 headwater sites, 30 surface runoff sites, 12 open ditch drains and 3 drainage wells, were sampled at two-week intervals during the 1970 irrigation season. Twenty-nine gravity-irrigated fields were included in the sampling program. The water samples were analyzed for nitrate, ammonia, organic nitrogen, soluble phosphorus, total phosphorus, total solids, electrical conductivity (total salts) and pH.

Data from the 1970 survey indicate that the concentrations of the three forms of nitrogen were relatively low in all of the water sources (Fitzsimmons et al., 1972). Except for isolated instances in which fertilizer materials were added directly to the irrigation water, the concentrations of the nitrogen forms in the surface runoff were essentially the same as those in the incoming irrigation water. In general, the groundwater sources contained the largest concentrations of nitrate-nitrogen and also contained relatively large concentrations of both soluble and total phosphorus. The surface runoff contained the largest concentrations of total phosphorus and total solids (mostly sediment). The concentrations of both of these constituents varied widely with location and time during the sampling period (Naylor et al., 1976).

The results of the first phase of this study showed how the concentrations of several pollutants varied in the Boise Valley as to water source, location, time of year and other factors. The quantities of pollutants either lost or gained from fields in the study area were not determined since flow measurements were not made. Also, the quality and quantity of deep percolation losses were not determined. To get this type of information, a 60.5-acre tract was monitored during the 1971 irrigation season to determine the net losses or gains of water, sediment and nutrients on gravity-irrigated fields in the tract (Busch et al., 1972). The experiment was repeated in 1972 on 90 acres of land. Sediment retention ponds constructed at the lower ends of two fields in the tract were included in the 1972 monitoring program. Sugarbeets and onions were the crops grown in 1971 and a field of beans was added in 1972.

Data from the 1971 and 1972 studies indicate that the quantity and quality of the return flows from fields in this tract varied considerably with the crops grown (Fitzsimmons et al., 1975). Although some of these differences were attributed to differences in water management practices (Busch et al., 1972 and Carlson, 1974). In general, practices which increased water-use efficiencies tended to reduce sediment and nutrient losses.

Seasonal data for the tract show that more nitrate-nitrogen and ammonia entered the tract with the incoming irrigation water than was lost in the surface runoff (Fitzsimmons et al., 1975). There was a net loss of total phosphorus and total solids from the tract. Factors influencing the loss of nutrients from this tract have been reported by Busch et al., (1975). These losses were found to be dependent on several independent variables including the amount of irrigation water retained on a field, the amount of total solids in the surface runoff and the amount of fertilizer materials applied in the irrigation water. Increasing the percentage of applied water retained on a field and reducing the amounts of fertilizer applied in the irrigation water would decrease the amounts of all nitrogen forms lost in the surface runoff.

The sediment retention ponds proved to be very effective in reducing sediment losses from the tract (Fitzsimmons et al., 1975). The data indicate that as much as 79 percent of the total solids carried from the fields by surface runoff was retained in the ponds. There was also a small general decrease in the nutrient load of the water during retention in the ponds (Bristol, 1973 and Yoo, 1974).

Since the 1970 Boise Valley water quality survey indicated that nitrate-nitrogen concentrations were greater in groundwater sources than they were in surface waters, research was initiated in 1973 to determine the quality of shallow groundwater and its influence on the quality of water in surface drain systems (Lewis et al., 1977). It was found that the complexity of underlying materials in the Boise Valley makes the interpretation of shallow groundwater quality data obtained at a given location very difficult. Irrigated agriculture appears to have two opposing effects: (1) enrichment of the groundwater during the crop growing season by the leaching of nutrients through the soil and (2) dilution of groundwater return flows by surface return flows.

Research was started in the spring of 1974 to determine both the effectiveness and cost impact of measures which might be used to control sediment, nutrient and other pollutant losses from irrigated lands in the Boise Valley (Fitzsimmons et al., 1975). Seven sites which were selected to represent the different soils, field slopes, crops and irrigation practices in the Valley were instrumented so that water, nutrient and suspended solids mass balances could be established for each site. These balances were used to determine the effectiveness of different water management practices and return flow measures in controlling pollutant discharges. Data relative to the initial investment costs and operating costs of sprinkler and surface irrigation systems and sediment retention ponds were gathered and used to prepare representative farm budgets for four alternative water management plans. Guidelines for controlling sediment and nutrient losses in the Valley were presented (Fitzsimmons et al., 1975).

The results of the 1974 study show how water, sediment and nutrient losses are influenced by water management practices, tillage and other cultural practices, soil type and field slope. The sediment loss data, for example, show that sediment losses are influenced more by management practices than by any other factor. Losses from a seed corn field, which was cultivated several times, were over fifty times as great as those from an alfalfa field which was cultivated very little. The loss from a dry bean field whose slope was about half that of the corn and alfalfa fields was more than three times the loss from the seed corn field. All three fields were on the same soil series. The amount of water applied during an irrigation and the associated stream size also affected sediment losses. Applying a given amount of water with double the stream size resulted in approximately a two-fold increase in both surface runoff and sediment losses. Doubling both the amount of water applied and the furrow stream size resulted in over a four-fold increase in sediment losses.

Data from the 1974 study show that there was a net loss of total phosphorus and suspended solids from the fields where surface runoff occurred (there was no surface runoff from the sprinkler-irrigated fields). The coefficient of determination (r^2) between the concentrations of total phosphorus and suspended solids was found to be 0.62. This indicates that most of the total phosphorus loss is associated with the loss of suspended solids and that cultural practices and physical conditions have very little effect on total phosphorus losses.

There were net seasonal gains of nitrate nitrogen on all of the fields studied. These gains ranged from 2.8 pounds per acre on a barley field to 15.2 pounds per acre on a hop field. Deep percolation losses on several of the fields resulted in significant losses of nitrate nitrogen from the root zones of these fields. Most of these losses were attributed to over irrigation and/or over fertilization.

Comparison of the budgets for a 200-acre farm which was assumed to be representative of the area indicates that the net return per acre using a gravity irrigation system is about $35 more than the return using a sprinkler irrigation system. It was concluded, however, that the analysis may have been biased towards gravity irrigation and that consideration of some of the advantages of sprinkler irrigation over gravity irrigation would make sprinkler systems more competitive from an economic standpoint.

Bondurant (1971) measured the quality of applied and runoff water from surface irrigation of a 536-acre tract on silt loam soil in the Magic Valley. He concluded that more nutrients were applied to the field in the irrigation water than were removed in the runoff water. Carter _et al._, (1974) tabulated data on total salt, specific ion and fertilizer element concentrations in the irrigation and drainage waters of the Twin Falls tract in the Magic Valley. These data were helpful in delineating water quality differences between surface return flows and subsurface drainage flows.

In connection with sediment pond design studies, Oliver (1974) and Ballard (1975) measured sediment yields from beans, grain and potatoes grown on silt loam soils in the Magic Valley. Ballard reported seasonal sediment yields from potatoes of up to 37 tons per acre and sediment removal efficiencies of ponds from 85 to 95 percent. Brockway (1976) reported measured sediment yields and the results of studies to determine the sediment removal efficiencies of ponds. He reported that from 82 to 91 percent of the sediment in the runoff from silt loam soils was removed. Corresponding phosphate removal efficiencies ranged from 35 to 78 percent.

Bondurant _et al._, (1975) used flow frequency analysis procedures to determine design flows for sediment ponds in drainageways. These studies indicate that 80 percent of the total seasonal flow in return streams in southern Idaho occurs at flow rates which are less than 50 percent of the maximum flow rates in these streams.

SECTION 5

STUDY AREAS

This study was conducted in two major irrigated areas in southern Idaho, the Boise Valley in southwestern Idaho and the Magic Valley in southcentral Idaho. Furrow irrigation is the prevalent method of applying water to croplands in these two areas. On some farms, irrigation water is applied so that there is little, if any, surface runoff and resulting pollutant losses. On others, however, the surface runoff and resulting sediment and other pollutant losses are relatively high. Data were gathered in this study to determine the effectiveness and cost impact of several methods for controlling sediment and other pollutant losses from irrigated lands in the two study areas. The purpose of this chapter is to provide information about the study areas which will be helpful in interpreting these data.

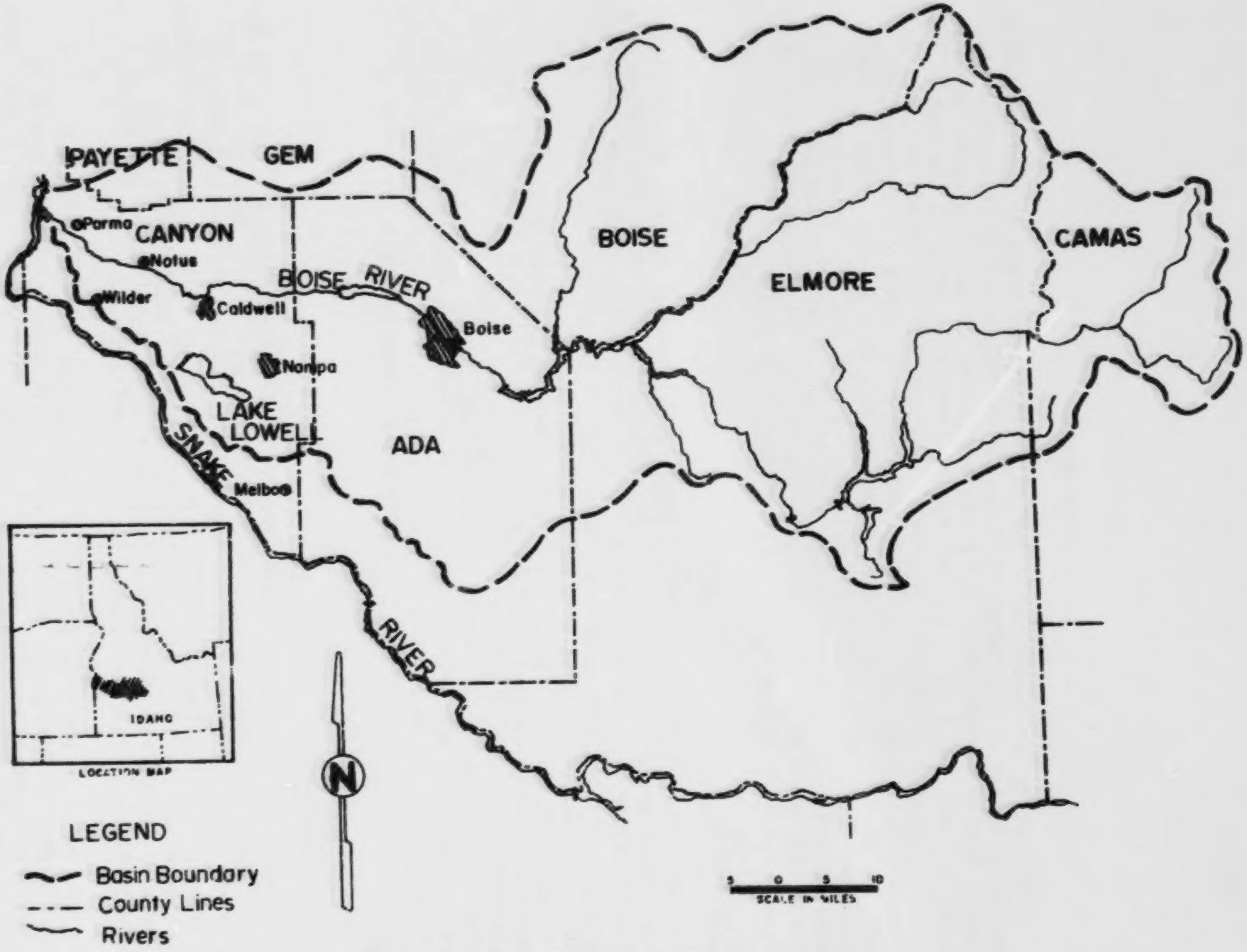
BOISE VALLEY

For this report, the Boise Valley is considered to include the irrigated area in the Boise River Basin from the city of Boise west to the Idaho-Oregon border (Figure 1). Field investigations were conducted in this area at sites located near the towns of Caldwell and Notus in Canyon County. Canyon County, with about 88,000 hectares of land under irrigation, is one of the more important agricultural counties in the state. Farming and food processing is an important segment of this county's economy. In 1972, for example, farming provided 20 percent of all personal income in the county and food processing accounted for another 9 percent of all personal income. The sale of crops and crop products accounted for 55 percent of the cash farm receipts in the county in 1972 and 59 percent of the receipts in 1973. Livestock and livestock products accounted for the remainder of these receipts (Bollinger, 1975).

Geology and Soils

The Boise Valley lies in an upland plain of unconsolidated lacustrine and fluvial materials deposited by the Boise and Snake Rivers. Terraces of these materials rise stepwise above the Boise River. Relief within the Valley is generally low. The lowland plain in the vicinity of Boise is about 810 meters above mean sea level. In the vicinity of Caldwell, local basalt ridges rise as much as 120 meters above the bottom land. The elevation of the valley floor at its western edge is slightly less than 670 meters.

The soils in the area are highly variable and complex. Those over the basalt ridges are generally quite shallow, while those over the lacustrine deposits are generally quite variable in depth. Duripans in many of the soils restrict the downward movement of water and plant roots. High water tables


PAYETTE
GEM
CANYON
Parma
Notus
Wilder
Caldwell
BOISE RIVER
Boise
Nampa
LAKE LOWELL
SNAKE
Melba
RIVER
ADA
BOISE
ELMORE
CAMAS
IDAHO
LOCATION MAP
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SCALE IN MILES
LEGEND
Basin Boundary
County Lines
Rivers

Figure 1. Map of the Boise River Basin.

are common in many parts of the Valley.

Climate

The Boise Valley area has a dry, temperate climate which is characterized by cool, wet winters and warm, dry summers. The mean annual temperature at Boise is 10.4°C and there is an average of 172 days between killing frosts. The average annual precipitation varies from about 150 millimeters (mm) in a strip along the Snake River to over 300 mm in the northeastern part of the Valley. The annual evaporation from open water surfaces in the area is about 840 mm.

Cropping and Irrigation Practices

Approximately 85 percent of the land in Canyon County is used for irrigated crops. Census of Agriculture figures on the number and size of all irrigated farms and irrigated farms with annual sales over $2,500 in Canyon County are given in Table 1. The census includes many part-time and hobby farms, many of which have annual sales of $2,500 or more.

The principal crops grown in the Boise Valley include sugarbeets, beans, potatoes, corn, alfalfa, wheat and barley. Hops, onions, mint and a number of seed crops are also grown in the Valley. Some of the area is used for orchards. The number of hectares of the major field crops grown in Canyon County is given in Table 2. Data from two sources are given for wheat, barley and potatoes. Discrepancies in the data arise from estimation errors and a difference in tabulation procedures. The Census of Agriculture tabulates farm area according to the location of the farm headquarters, regardless of whether or not the land actually lies within the same county. The Statistical Reporting Service, on the other hand, attempts to show how much cropland area is within a county's boundaries.

The surface water used for irrigation in the Boise Valley is obtained mainly from the Boise and Payette Rivers. A complex network of lined and unlined canals is used to distribute the water to over 127,000 hectares of land in organized irrigation districts in the area. Most of the farms in this area are gravity irrigated, primarily through the use of siphon tubes and furrow methods. Although sprinkler irrigation is practiced in the Valley, its use is not very extensive at present. Surface and subsurface irrigation return flows are collected by a complex network of open ditch drains. Many of these drains return all or a portion of their flow to the delivery system for reuse.

Water-use data for 23 irrigation districts in the Boise Valley show that deliveries varied from 700 to 2,440 mm (2.3 to 8.0 acre-feet per acre) in 1970 (Fitzsimmons et al., 1975). The average delivery was 1,300 mm (4.25 acre-feet per acre). The consumptive use requirements for the crops grown in the districts ranged from 551 to 648 mm. The water-use efficiency (percentage of water delivered to a district used consumptively by the crops grown in the district) ranged from 24 to 84 percent. The overall average for the valley in 1970 was 46 percent.

TABLE 1. NUMBER AND SIZE OF IRRIGATED FARMS IN CANYON COUNTY

	1969[1]	1974[2]
All Irrigated Farms		
Number	2,033	1,837
Irrigated area (ha)	87,916	84,888
Average irrigated area per farm (ha)	43.2	46.2
Irrigated Farms With Sales of $2,500 or More		
Number	1,594	1,419
Irrigated area (ha)	84,508	82,220
Average irrigated area per farm (ha)	53.0	57.9

[1] 1969 Census of Agriculture

[2] 1974 Census of Agriculture, Preliminary Report, Canyon County (Issued May, 1976)

TABLE 2. MAJOR FIELD CROPS GROWN IN CANYON COUNTY

Crop	Census of Agriculture[1] Hectares		Statistical Reporting[2] Service Hectares	
	1969	1974	1969	1974
Alfalfa Hay	12,231	13,032		
Sugarbeets	14,098	9,423		
Wheat	4,183	10,829	7,689	10,239
Barley	9,775	8,629	7,770	10,036
Corn Silage	4,596	5,358		
Potatoes	5,097	4,941	2,185	3,035
Alfalfa Seed	4,887	NA[3]		
Dry Beans	2,635	NA		
Sweet Corn Seed	2,473	NA		
Corn Grain	2,424	2,296		

[1] 1969 Census of Agriculture and 1974 Census of Agriculture, Preliminary Report, Canyon County (Issued May, 1976). Figures are for farms with sales of $2,500 or more.

[2] 1976 Idaho Agricultural Statistics

[3] Data not available (NA)

MAGIC VALLEY

The Magic Valley is generally considered to include the irrigated area of the Snake River drainage in southcentral Idaho from the city of Bliss on the west to Burley and Rupert on the east (Figure 2). It comprises all or portions of the following counties: Cassia, Gooding, Jerome, Lincoln, Minidoka and Twin Falls. Field investigations were conducted in this area at sites located in Jerome and Twin Falls Counties.

Geology and Soils

Most of the land in the Magic Valley lies in an area designated as the Snake River plain. Land north of the Snake River is underlain by the Snake Plain aquifer. This aquifer, which consists of intercalated pyroclastic and sedimentary materials, extends from Bliss eastward nearly to the eastern border of the state. The Snake Plain aquifer is recharged by natural runoff from northside streams, precipitation and deep percolation from irrigation diversions from the Snake River. Well yields are large and the aquifer supplies water for over 230,000 hectares of irrigated land. Land south of the river slopes northward from foothills and is underlain by basalts and rhyolites at varying depths.

Elevations in the Magic Valley vary from 1,150 meters above mean sea level at Twin Falls to 1,387 meters at Hollister. Abrupt changes in the local relief occur near volcanic buttes and cinder cones and along the Snake River gorge. Near Twin Falls, the gorge is approximately 140 meters deep.

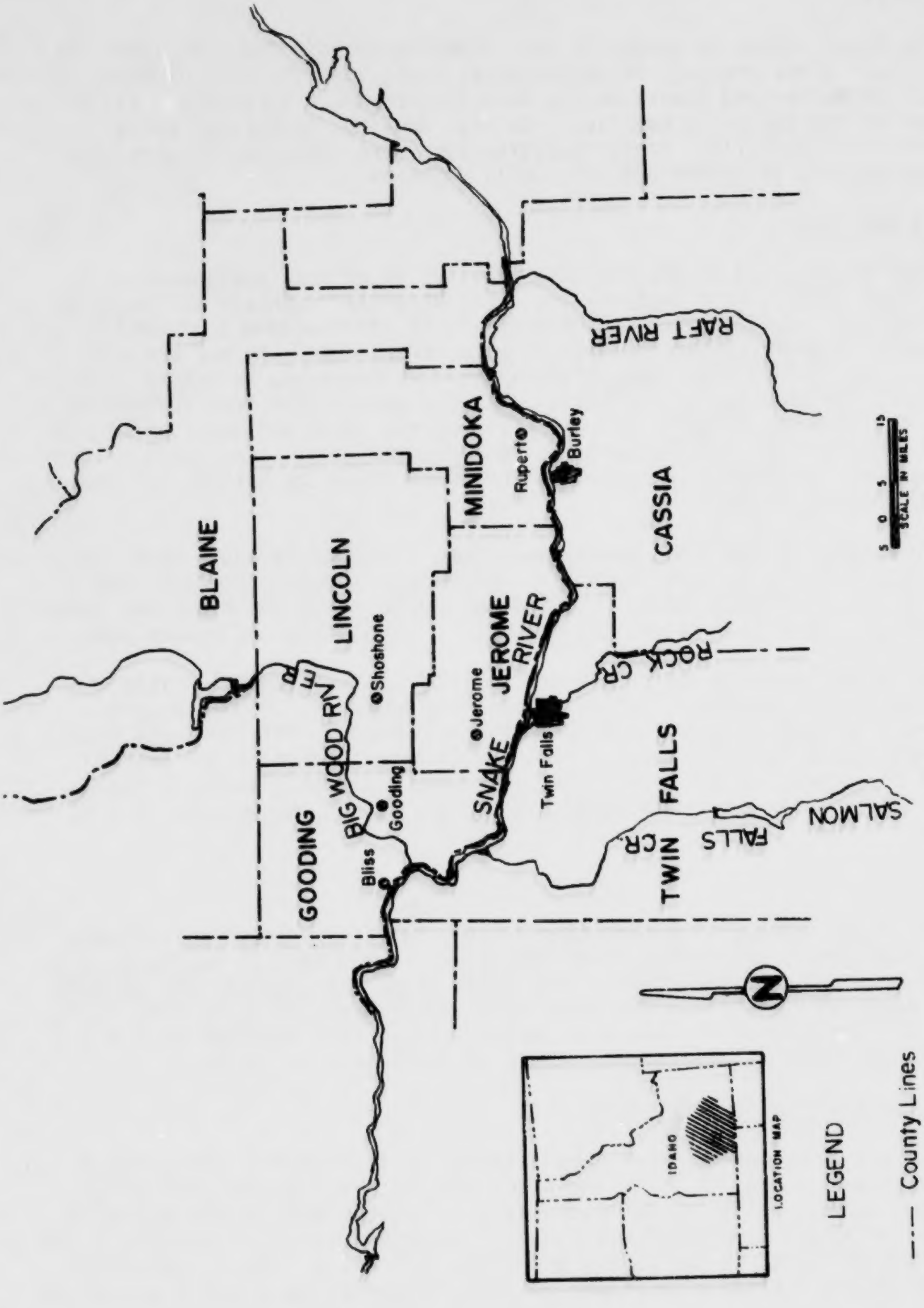
The major soils in the area are silt loam soils of loessal origin with calcareous loamy subsoils. The silt loams are generally underlain by a calcareous hardpan at a depth of 60 to 90 centimeters. This cemented layer is permeable but it does restrict root penetration. Soils in the Gooding-Wendell area north of the river generally range from sandy loams to loamy sands. These soils are quite permeable and are highly susceptible to wind erosion.

Climate

The Magic Valley, like the Boise Valley, has a dry, temperate climate. The average annual precipitation at Twin Falls is 230 mm. It increases with elevation to 260 mm north of the Snake River at Shoshone and to 300 mm south of the river at Hollister. The mean maximum July temperature at Twin Falls is 33° C. The mean minimum January temperature at this location is 7.5° C. The average length of the growing season at Twin Falls is 133 days.

Irrigation and Cropping Practices

Irrigation commenced in the Magic Valley about 1910 with the construction of mutual canal companies under the Carey Act and the 1902 Reclamation Act. Water for approximately 197,000 hectares of irrigated land in the Valley is diverted or pumped from the Snake River. Diversions for 1976 for each of the irrigation districts in the Valley are given in Table 3. The locations of these districts are shown in Figure 3. The portion of the A and B Irrigation


BLAINE
LINCOLN
GOODING
MINIDOKA
JEROME
CASSIA
TWIN FALLS
SNAKE RIVER
BIG WOOD RIVER
RAFT RIVER
ROCK CR.
SALMON FALLS CR.
Shoshone
Gooding
Bliss
Jerome
Twin Falls
Rupert
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LOCATION MAP
LEGEND
County Lines
Rivers

Figure 2. Map of the Magic Valley area.

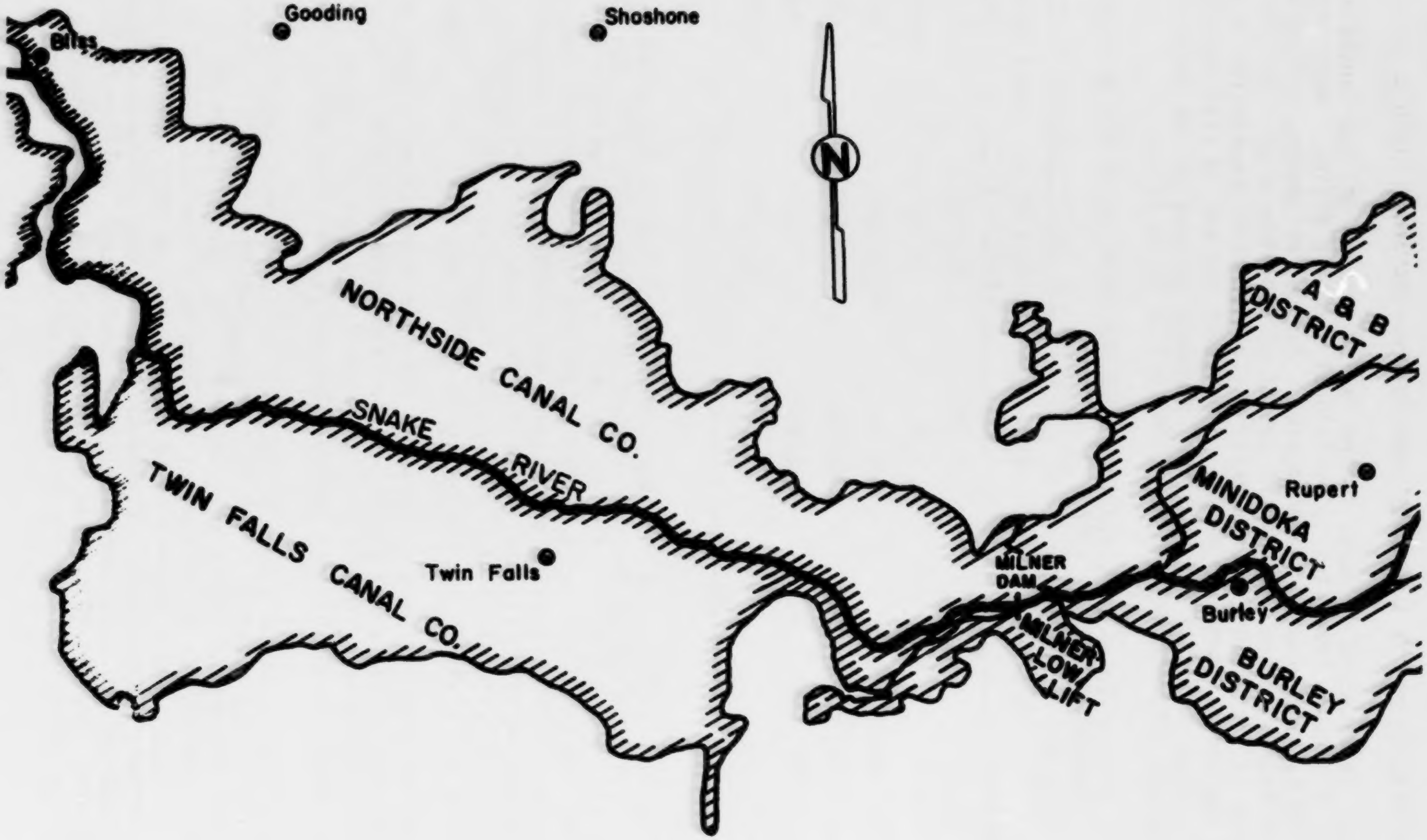

Bliss
Gooding
Shoshone
N
NORTHSIDE CANAL CO.
SNAKE RIVER
TWIN FALLS CANAL CO.
Twin Falls
A & B DISTRICT
Rupert
MINIDOKA DISTRICT
MILNER DAM
MILNER LOW LIFT
Burley
BURLEY DISTRICT

Figure 3. Major irrigation districts in the Magic Valley area.

District (25,325 ha) is served by pumping from the Snake Plain aquifer.

Water is conveyed to farms in the Valley through unlined canals and is distributed through headgates to individual farms or fields. Most of the deliveries are measured at the headgates. Furrow irrigation, through the use of siphon tubes, is the predominant method of applying water. The use of gated pipe is increasing and sprinkler irrigation from groundwater or existing surface sources is common. The use of pumpback systems is also increasing. Aerial surveys show that the number of pumpback systems in the Twin Falls Canal Company area increased from 13 in 1974 to 34 in 1976.

TABLE 3. IRRIGATION WATER DIVERSIONS FROM THE SNAKE RIVER FOR DISTRICTS IN THE MAGIC VALLEY, 1976

District	Area (ha)	Diversion (1000 m^3)	Unit Diversion (mm)
Burley	19,420	316,763	1,631
A & B	5,875	62,057	1,055
Twin Falls Canal Company	82,012	1,290,611	1,573
Northside Canal Company	64,736	1,259,897	1,945
Milner Lowlife	5,450	73,936	1,356
Minidoka	29,130	560,665	1,923

Irrigation efficiences have been measured on some of the districts in the Valley. Data reported by the U.S. Bureau of Reclamation (1971) for the A Division of the A & B District indicate that on-farm irrigation efficiences varied from 36 to 44 percent and that attainable efficiencies varied from 51 to 64 percent. Data reported by Claiborn and Brockway (1975) for the A & B, Northside and Burley Districts indicate that the project efficiencies for these districts were 42, 23 and 19 percent, respectively, in 1974. The estimated on-farm irrigation efficiences were 62, 39 and 25 percent, respectively.

Drainage problems have occurred in the Twin Falls Canal Company area on the south side of the Snake River. These have been corrected by installation of subsurface drainage tunnels into the underlying basalts. Areas of Minidoka County in the eastern part of the valley have high water tables.

The principal crops grown in the Magic Valley include sugarbeets, beans, grain, alfalfa and potatoes. The sale and processing of crops is quite important to the economy of this area. In Twin Falls County, for example, the sale of crops accounted for 57 percent of the cash farm receipts in 1972 and 65 percent in 1973. These figures for Jerome County for 1972 and 1973 are 48 and 56 percent, respectively. Livestock and livestock products accounted for the remainder of the cash farm receipts in each county (Bollinger, 1975). In 1972, farming provided 22 percent of the personal income generated in these two counties and food processing generated another 5 percent.

Figures from the Census of Agriculture on the number and average size of the irrigated farms in Jerome County are presented in Table 4. Similar data for Twin Falls County are given in Table 5. Data on the number of hectares of the major field crops grown in Jerome and Twin Falls Counties are presented in Tables 6 and 7, respectively. Data from two sources are given for wheat, barley and potatoes. As explained previously, discrepancies in the data are probably due to differences in the tabulation procedures used by the two agencies.

TABLE 4. NUMBER AND SIZE OF IRRIGATED FARMS IN JEROME COUNTY

	1969[1]	1974[2]
All Irrigated Farms		
Number	801	724
Irrigated area (ha)	49,958	49,648
Average irrigated area per farm (ha)	62.4	68.6
Irrigated Farms With Sales of $2,500 or More		
Number	749	674
Irrigated area (ha)	49,465	49,282
Average irrigated area per farm (ha)	66.0	73.1

[1] 1969 Census of Agriculture

[2] 1974 Census of Agriculture, Preliminary Report, Jerome County (Issued May, 1976)

TABLE 5. NUMBER AND SIZE OF IRRIGATED FARMS IN TWIN FALLS COUNTY

	1969[1]	1974[2]
All Irrigated Farms		
Number	1,509	1,405
Irrigated area (ha)	100,790	94,704
Average irrigated area per farm (ha)	66.8	67.4
Irrigated Farms with Sales of $2,500 or More		
Number	1,387	1,276
Irrigated area (ha)	99,892	93,897
Average irrigated area per farm (ha)	72.0	73.6

[1] 1969 Census of Agriculture

[2] 1974 Census of Agriculture, Preliminary Report, Twin Falls County, (Issued May, 1976)

TABLE 6. MAJOR FIELD CROPS GROWN IN JEROME COUNTY

Crop	Census of Agriculture[1] Hectares 1969	Census of Agriculture[1] Hectares 1974	Statistical Reporting Service[2] Hectares 1969	Statistical Reporting Service[2] Hectares 1974
Alfalfa Hay	13,005	13,346		
Wheat	4,230	10,837	4,816	9,753
Dry Beans	7,917	NA[3]		
Potatoes	4,253	4,790	4,452	5,342
Barley	2,940	2,296	3,238	3,238
Sugarbeets	3,066	879		

[1] 1969 Census of Agriculture and 1974 Census of Agriculture, Preliminary Report, Jerome County (Issued May, 1976). Figures are for farms with sales of $2,500 or more.

[2] 1976 Idaho Agricultural Statistics

[3] Data not available (NA)

TABLE 7. MAJOR FIELD CROPS GROWN IN TWIN FALLS COUNTY

Crop	Census of Agriculture[1] Hectares 1969	Census of Agriculture[1] Hectares 1974	Statistical Reporting Service[2] Hectares 1969	Statistical Reporting Service[2] Hectares 1974
Alfalfa Hay	21,917	23,690		
Dry Beans	21,345	24,822		
Wheat	10,255	15,716	11,250	14,124
Barley	5,097	5,052	5,747	4,937
Sugarbeets	9,343	3,323		
Potatoes	3,000	5,968	3,278	6,677
Mixed Grain	4,757	1,911		
Field & Seed Peas	3,268	3,389		

[1] 1969 Census of Agriculture and 1974 Census of Agriculture, Preliminary Report, Twin Falls County (Issued May, 1976). Figures are for farms with sales of $2,500 or more.

[2] 1976 Idaho Agricultural Statistics

SECTION 6

BOISE VALLEY FIELD INVESTIGATIONS

The main purpose of the field investigations conducted in the Boise Valley was to evaluate the effects of management practices and sediment removal systems on the quality and quantity of the surface runoff from irrigated fields. On-farm sites were instrumented and monitored so that the effects of different irrigation, cropping and tillage practices, as well as other factors, could be determined. In addition, sediment removal devices installed at the on-farm sites were evaluated to determine their effectiveness in removing sediment and other pollutants from surface runoff. One of these devices, a small on-farm pond, is shown under construction in Figure 4. Two large district-type sediment retention ponds, such as the one shown in Figure 5, were also monitored to determine their effectiveness in improving the quality of return flows from large irrigated areas.

A total of nine on-farm sites were monitored during the 1975 and 1976 irrigation seasons. Field, crop and other data for these sites are given in Table 8. Sites 2, 3 and 4 were located adjacent to each other in a large field at the Caldwell Research and Extension Center. Site 1 was located in a cooperator's field which is adjacent to the Caldwell Center. Site 9 was located at the Parma Research and Extension Center. The rest of the sites (Sites 5, 6, 7 and 8) were located in cooperators' fields near Notus. Descriptions of the soils at each site are given in Tables 9 and 10.

The surface runoff from all but one of the field sites was diverted through one or more sediment retention devices. In 1976, for example, small T-shaped basins (T-slots) were dug in the tailwater ditch at the lower end of Site 1. One of these basins is shown in Figure 6. The runoff from Site 1 flowed through the T-slots before it entered the sediment retention pond at this site. In 1975, the surface runoff from Sites 3 and 4 passed through a grass buffer strip before it entered a sediment pond. A densely seeded strip of barley (Figure 7) was used as a buffer strip at Sites 2, 3 and 4 in 1976.

Several different practices were evaluated at each study site to determine their effects on the quality of the surface runoff leaving the sites. These included irrigation scheduling, furrow stream size, run length, cultivation practices and fertilization practices. Additional and/or more stringent management practices were imposed on the sites at the Caldwell and Parma Centers (Sites 2, 3, 4 and 9.) These practices included preplant irrigations; careful management of the furrow stream size in relation to run length, slope and soil conditions; cutback streams to minimize runoff; and proper irrigation scheduling based on soil moisture readings and climatic data.

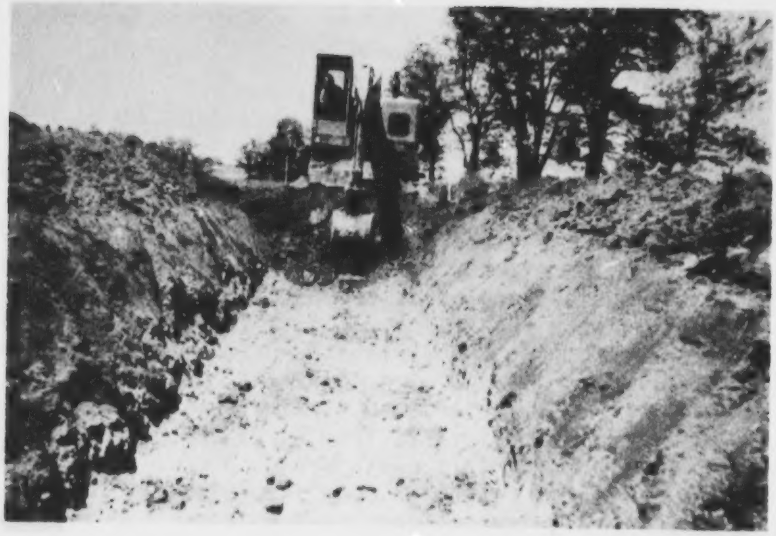


Figure 4. On-farm sediment pond under construction.

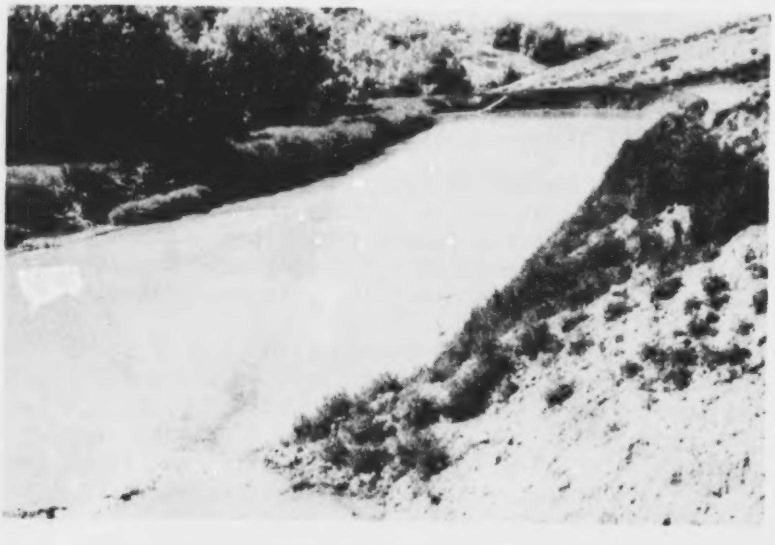


Figure 5. Large sediment retention pond located in a natural drainageway near Wilder, Idaho.

TABLE 8. BOISE VALLEY ON-FARM STUDY SITES

Site	Year	Crop	Area (ha)	Length (m)	Average Slope (%)	Sediment Retention Device(s)
1	1975	Corn	1.76	237	2.6	Small Pond
	1976	Corn	1.76	237	2.6	T-Slots & Small Pond
2	1975	Corn	1.89	345	2.7	Sediment Pond
	1976	Corn	1.78	345	2.7	Grain Strip & Pond
3	1975	Corn	1.84	327	2.9	Grass Strip & Pond
	1976	Corn	1.74	327	2.9	Grass Strip & Pond
4	1975	Corn	1.76	321	2.9	Grass Strip & Pond
	1976	Corn	1.66	321	2.9	Grain Strip & Pond
5	1975	Hops	14.45	383	1.1	Sediment Pond
	1976	Hops	14.45	383	1.1	Sediment Pond
6	1975	Seed Alfalfa	8.23	386	1.1	Sediment Pond
	1976	Seed Alfalfa	8.23	386	1.1	Sediment Pond
7	1975	Barley	6.76	386	1.1	Sediment Pond
	1976	Seed Alfalfa	6.76	386	1.1	Sediment Pond
8	1975	Sugarbeets	2.00	386	0.7	Sediment Pond
	1976	Barley	2.00	386	0.7	Sediment Pond
9	1976	Corn	0.89	187	1.2	None

TABLE 9. DESCRIPTION OF THE SOILS FOUND ON THE BOISE VALLEY STUDY SITES

Site	Soil Series	General Characteristics
1	Purdam Silt Loam	Medium textured soils that have a weakly cemented duripan at a depth of 50 to 100 centimeters. These soils formed in a moderately deep loess mantle over medium textured or moderately coarse textured alluvium or lacustrine sediments.
2,3,4	Purdam Silt Loam, Vickery-Marsing Silt Loams	These sites are a complex of Purdam and Vickery-Marsing silt loams. Vickery soils differ from Purdam soils mostly by having an indurated or strongly cemented layer at a depth of 50 to 100 centimeters instead of a weakly cemented duripan. Marsing soils are similar to the Purdam and Vickery soils except they do not have a duripan or cemented layer.
5	Greenleaf-Owyhee Silt Loams, Power-Purdam Silt Loams	This site is a complex of soil series. The Greenleaf series consists of medium textured and moderately fine textured, well drained soils formed in laminated medium textured lacustrine material and old alluvium that is overlain by loess in places. Greenleaf soil has a B2t layer from about 20 to 35 centimeters which is a light silty clay loam. Owyhee series is similar to Greenleaf series only without the heavier textured subsoil. Power and Purdam soils are similar except the Power soil lacks the duripan at 50 to 100 centimeters.
6,7,8,9	Greenleaf-Owyhee Silt Loams,	These sites are a complex of soil series. The Greenleaf-Owyhee series is the same as described for Site 5. Nyssaton silt loam has similar characteristics on the surface as the Owyhee series but has an Ap, Clca, C2ca horizon sequence instead of the Ap, B, Clca horizon sequence of the Owyhee series.

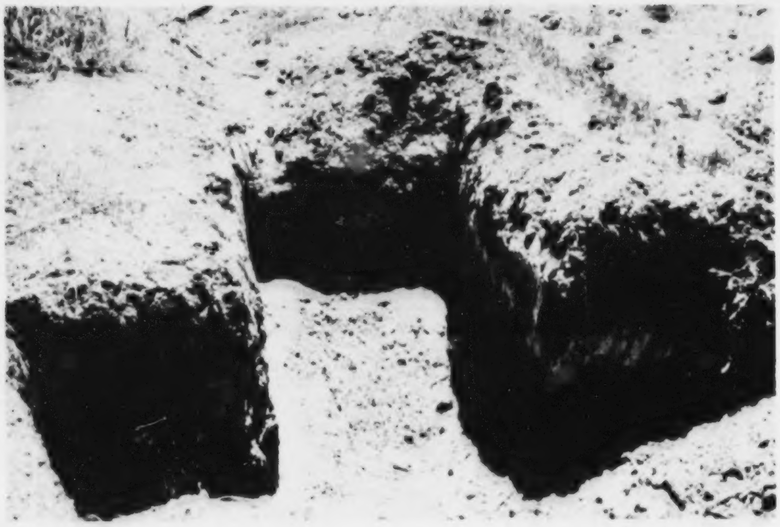


Figure 6. T-slot installed at Site 1 in 1976.

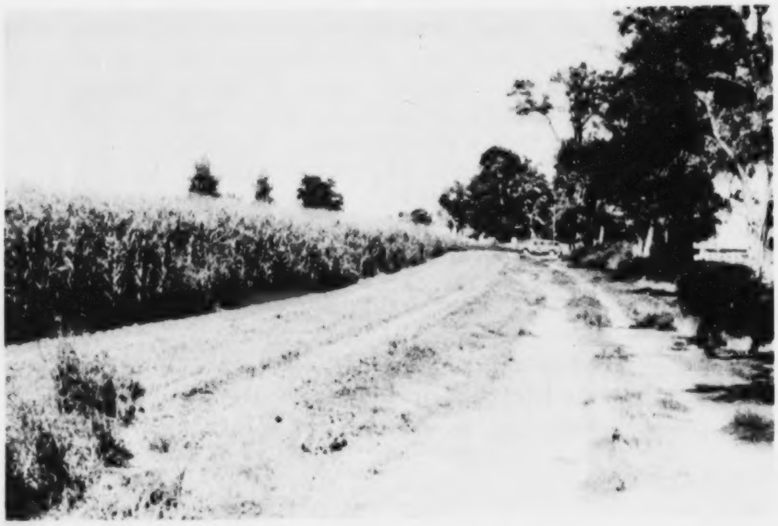


Figure 7. Vegetated buffer strip seeded at the lower ends of Sites 2, 3 and 4 in 1976.

TABLE 10. PARTICLE SIZE DISTRIBUTION OF SURFACE LAYER (TOP 30 CENTIMETERS) OF SOILS FROM THE BOISE VALLEY STUDY SITES

Site	Total Sand (%)	Total Silt (%)	Total Clay (%)	Texture Class
1	25.11	62.65	12.24	Silt Loam
2,3,4	21.85	63.55	14.60	Silt Loam
5	26.95	60.20	12.85	Silt Loam
6,7,8,9	11.07	73.69	15.24	Silt Loam

All study sites were instrumented so that water, nutrient and total suspended solids balances could be established for each site and sediment pond. Water measurement devices equipped with stage recorders were installed so that all water entering and leaving each site and sediment pond could be continuously measured. Two of these installations are shown in Figures 8 and 9. A modification of the procedure presented by Jensen et al., (1971) was used to estimate evapotranspiration on a daily basis for the crop on each site.

Samples of head and tailwater flows were taken at frequent intervals during each irrigation set. Tailwater samples were usually taken at one-hour intervals as runoff commenced and at two to four-hour intervals during the remainder of the set. All samples were immediately frozen for storage and transport to the laboratory for analysis.

The water samples were analyzed for nitrate, ammonia, organic nitrogen, soluble (ortho) phosphorus, total phosphorus, total suspended solids, turbidity, electrical conductivity and pH. A Technicon Autoanalyzer was used for determining the nitrogen forms. Samples were filtered through 0.45 μ millipore filters to determine soluble phosphorus and digested with sulfuric acid and ammonium persulfate for total phosphorus. Phosphorus was determined colorimetrically in the filtrate and digestion mixture by the ascorbic acid-molybdenum blue method. Suspended solids were measured by drying and weighing the residue obtained after passing an aliquot of sample through a 0.45 μ millipore filter. Turbidity was obtained using a Model 104 Ecolab Turbidimeter. Electrical conductivity was determined with a Solu-Bridge and pH with a glass electrode.

Water, suspended solids and nutrient balances were established for each site for the 1975 and 1976 irrigation seasons. Balances were also established for each irrigation and each set within an irrigation.

MANAGEMENT PRACTICES

Water, nutrient and sediment losses from the study sites were affected by the water management and cultural practices used at each site. Specific practices and other factors evaluated in this study included furrow stream size, irrigation scheduling, alternating furrows, preplant irrigation, seasonal changes, tillage practices and crops grown.

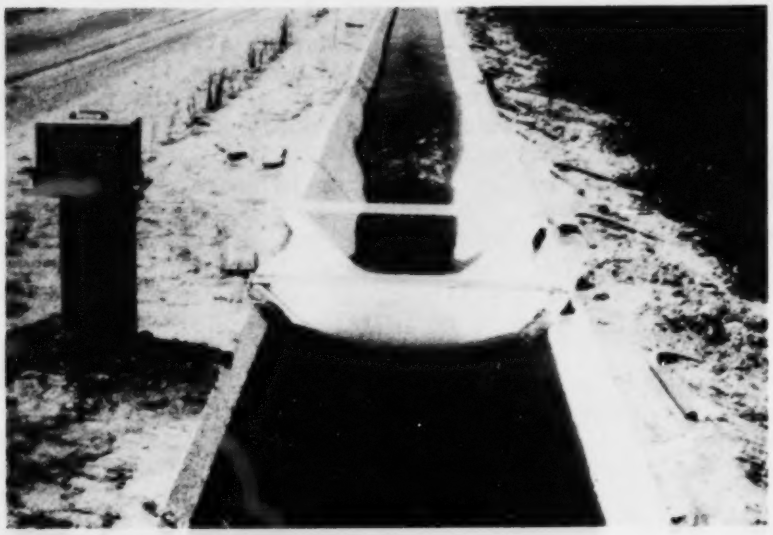


Figure 8. Flume and recorder used to obtain a continuous record of the flow onto a study site.

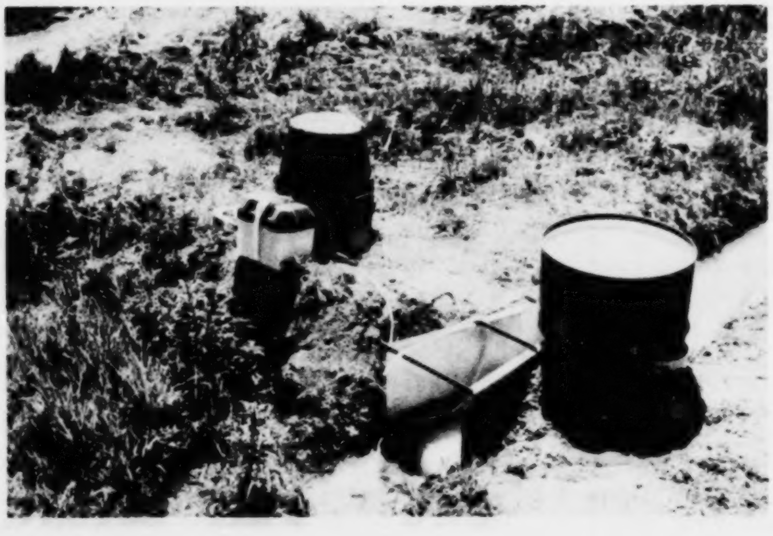


Figure 9. Flume and automatic sampler used to monitor flow from a site.

Furrow Stream Size

The plots at Sites 2, 3 and 4 were irrigated five times during the 1976 irrigation season with different sizes of furrow streams. Stream size and pollutant loss data for each site are given in Table 11. A stream of 0.767 liters per second was used to irrigate Site 2 during the first three irrigations. This stream was reduced to approximately 0.6 liters per second during the last two irrigations to limit runoff. At Site 3, the furrow stream was cut back to one-half its initial size after 12 hours during the first three irrigations. During the last two irrigations, the furrow stream was reduced to approximately 0.6 liters per second but was not cut back. A stream of approximately 0.4 liters per second was used to irrigate Site 4. This stream had to be increased to over 0.6 liters per second during the last two irrigations to get the wetting front to advance properly.

The sediment loss during the first irrigation of the season is usually greater than it is during subsequent irrigations (Mech and Smith, 1967). This was the case for Sites 2 and 3. However, the sediment loss from Site 3 (with cutback) was almost one-third less than the loss from Site 2 (without cutback) during the first irrigation. The sediment losses from both sites were much less during the last four irrigations than they were during the first irrigation. The seasonal totals (Table 12) show that the net sediment loss from Site 3 (with cutback) was over 16 percent less than the net loss from Site 2 (without cutback). The use of a small stream size on Site 4 resulted in a net gain of sediment on this plot during the first three irrigations. However, the sediment losses during the last two irrigations were nearly the same as those from the other two sites. The overall effect of using a reduced stream size during the first three irrigations is shown by the seasonal total which indicates a net sediment retention of over 1,100 kg/ha on this plot.

The runoff from all three plots was sampled after it had passed through a vegetated buffer strip and had flowed to the sampling point in a ditch which had a slope of 0.5 percent. As a result, a portion of the sediment retention shown for these sites occurred in the buffer strip and in the drainage ditch.

Total phosphorus losses from Sites 2 and 3 were minimal. The net retention of total phosphorus on Site 4 is related to the net sediment retention, since total phosphorus losses are associated with sediment losses (Fitzsimmons et al., 1972 and Naylor et al., 1976). The net retention of nitrate at all three sites was due to the fact that nitrate moves into the soil with the irrigation water. Similar results have been obtained at other sites in the Boise Valley (Busch et al., 1972 and Fitzsimmons et al., 1975).

Although reduced stream sizes resulted in significant reductions in pollutant losses from Sites 3 and 4, the overall irrigation efficiencies for the plots did not vary greatly. The data in Table 13 show that approximately the same amount of water was applied to each of the three plots; however, the amounts lost to surface runoff and deep percolation varied considerably. The water lost to deep percolation could be carrying soluble materials such as nitrate-nitrogen below the root zone.

TABLE 11. RESULTS OF THE BOISE VALLEY FURROW STREAM SIZE STUDY, 1976

Site	Irrigation	Set Length (hr)	Stream Size (l/s)	Net Sediment Loss (kg/ha)	Net Total P Loss (kg/ha)	Net Nitrate Loss (kg/ha)
2	1	24	0.767	2456	1.42	0.09
3	1	36	0.767, 0.384[1]	1647	1.36	0.07
4	1	48	0.396	-656[2]	-0.17	-0.18
2	2	24	0.767	395	0.04	-0.26
3	2	36	0.767, 0.384	744	0.60	-0.15
4	2	24	0.407	-508	-0.06	-0.33
2	3	24	0.767	183	-0.06	-0.37
3	3	36	0.767, 0.384	155	0.29	-0.32
4	3	48	0.407	-140	-0.19	-0.35
2	4	24	0.599	200	0.15	-0.06
3	4	24	0.599	142	0.01	-0.20
4	4	24	0.609	69	-0.07	-0.45
2	5	24	0.599	24	-0.03	-0.50
3	5	24	0.600	105	0.0	-0.37
4	5	24	0.643	123	0.01	-0.40

[1] Stream was cutback to smaller flow rate after 12 hours.

[2] Negative numbers indicate net gains.

TABLE 12. SEASONAL TOTALS FOR THE BOISE VALLEY FURROW STREAM SIZE STUDY, 1976

Site	Net Sediment Loss (kg/ha)	Net Total P Loss (kg/ha)	Net Nitrate Loss (kg/ha)
2	3,258	1.52	-1.10[1]
3	2,793	2.26	-0.97
4	-1,112	-0.48	-1.71

[1] Negative numbers indicate net gains

TABLE 13. WATER BALANCE RESULTS FOR THE BOISE VALLEY FURROW STREAM SIZE STUDY, 1976

Site	Water Applied (mm)	Surface Runoff (mm)	Deep Percolation (mm)	Water-Use[1] Efficiency (%)
2	802	218	216	52
3	692	179	146	61
4	749	125	257	56

[1] Percentage of water applied going to consumptive use

An in-depth study of a well-managed cutback irrigation system was carried out at Site 9 in 1976. Two adjacent plots were simultaneously irrigated five times throughout the season. The control plot was irrigated using constant stream sizes for 24-hour irrigation sets. The stream size in the cutback system was reduced an average of five times during each 24-hour set to limit the runoff per furrow to less than 0.041 liters per second (l/s). A summary of the initial and final stream sizes for each system is shown in Table 14.

The data in Table 14 also show that the cutback plot received 52 percent of the amount of water applied to the control plot. The resulting water-use efficiency of the cutback system was almost twice that of the non-cutback system.

Careful management of the cutback system reduced the amounts of pollutants lost from the cutback plot. As indicated by the data in Table 15, the net sediment loss from the cutback plot was less than 7 percent of the loss from the control or non-cutback plot. The net loss of total phosphorus from the cutback plot was negligible. Both plots showed a similar net gain of nitrate-nitrogen because approximately the same amount of water was infiltered

TABLE 14. FLOW AND WATER-USE DATA FOR THE FURROW CUTBACK STUDY AT SITE 9, 1976

Irrigation Number	Stream Size (l/s)				Water Applied (mm)		Water-Use Efficiency (%)[1]	
	Cutback		Non-Cutback		Cutback	Non-Cutback	Cutback	Non-Cutback
	Initial	Final	Initial	Final				
1	0.593	0.158	0.347	0.322	111	151	81	65
2	0.562	0.189	0.347	0.322	106	160	74	59
3	0.498	0.177	0.517	0.511	106	252	81	38
4	0.500	0.211	0.505	0.511	110	254	77	28
5	0.473	0.183	0.461	0.429	101	217	76	27
Totals					534	1,034		
Averages	0.525	0.184	0.435	0.419			78	41

[1] Percentage of water applied going to consumptive use

TABLE 15. NET SEDIMENT, PHOSPHORUS AND NITRATE LOSSES FROM CUTBACK AND NON-CUTBACK PLOTS AT SITE 9, 1976

Irrigation Number	Net Sediment Loss Cutback (kg/ha)	Net Sediment Loss Non-Cutback (kg/ha)	Net Total P Loss Cutback (kg/ha)	Net Total P Loss Non-Cutback (kg/ha)	Net Nitrate Loss Cutback (kg/ha)	Net Nitrate Loss Non-Cutback (kg/ha)
1	411	1,603	0.10	0.96	-0.76	-0.73[1]
2	388	3,637	0.27	2.70	-0.69	-0.77
3	81	5,230	-0.08	3.13	-1.19	-1.79
4	34	2,327	-0.14	0.99	-0.95	-0.51
5	1	737	-0.08	0.47	-0.80	-0.38
Totals	915	13,534	0.07	8.25	-4.39	-4.18

[1] Negative numbers indicate net gains

into each plot during the season.

During the second irrigation, the initial rate of runoff from the cutback plot was approximately the same as that from the control plot. However, it soon dropped to a much lower level as shown by the data plotted in Figure 10. As a result, the sediment concentration in the outflow dropped after an initial peak (Figure 11). The plot in Figure 12 shows that there was little additional loss of sediment from the cutback plot after 120 minutes of runoff; whereas, the loss from the control plot increased steadily during the second irrigation.

Irrigation Scheduling

Irrigation scheduling can have an effect on sediment and nutrient losses from a field as well as an effect on crop yields (Busch *et al.*, 1972). If a field is over-irrigated or irrigated too frequently, the resulting surface runoff will be excessive and will carry excessive amounts of sediment and other pollutants from the field. Reducing the number of irrigations and the amount of water applied will usually reduce the losses from a particular field. This was the case for Site 1. The number of irrigations at this site was reduced from eight in 1975 to six in 1976, partially as a result of a 15 percent decrease in the consumptive use requirements of the crop. As shown in Table 16, reducing the number of irrigations resulted in a 21 percent reduction in the amount of water applied, a 31 percent reduction in the amount of surface runoff, and a 25 percent reduction in the net amount of sediment lost from the plot.

The water-use efficiences (percentage of water applied used to meet the consumptive use requirements of the crop) were quite low both years. However, these efficiencies are about as high as can be expected for a furrow system

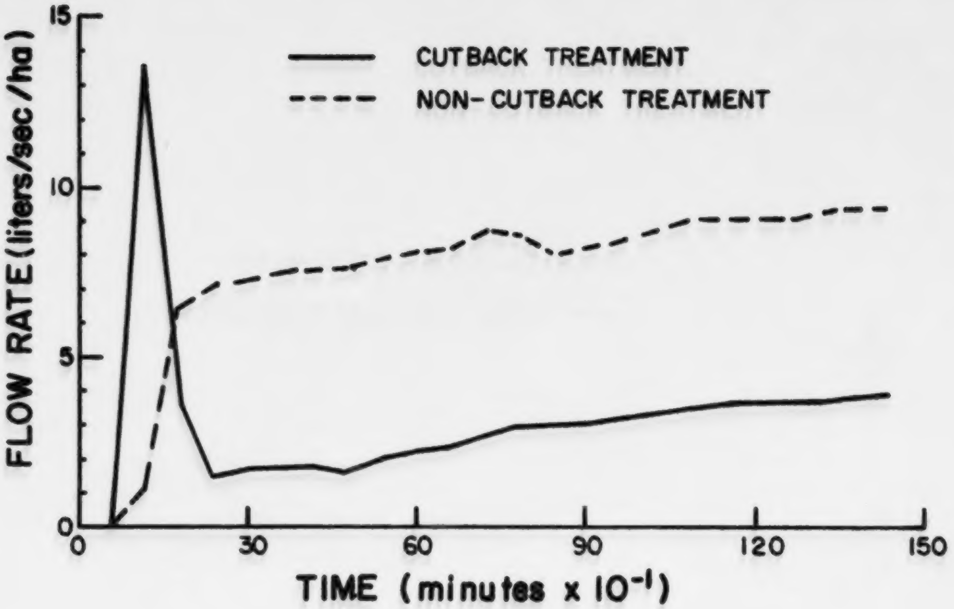


Figure 10. Rate of runoff from Site 9 during the second irrigation in 1976.

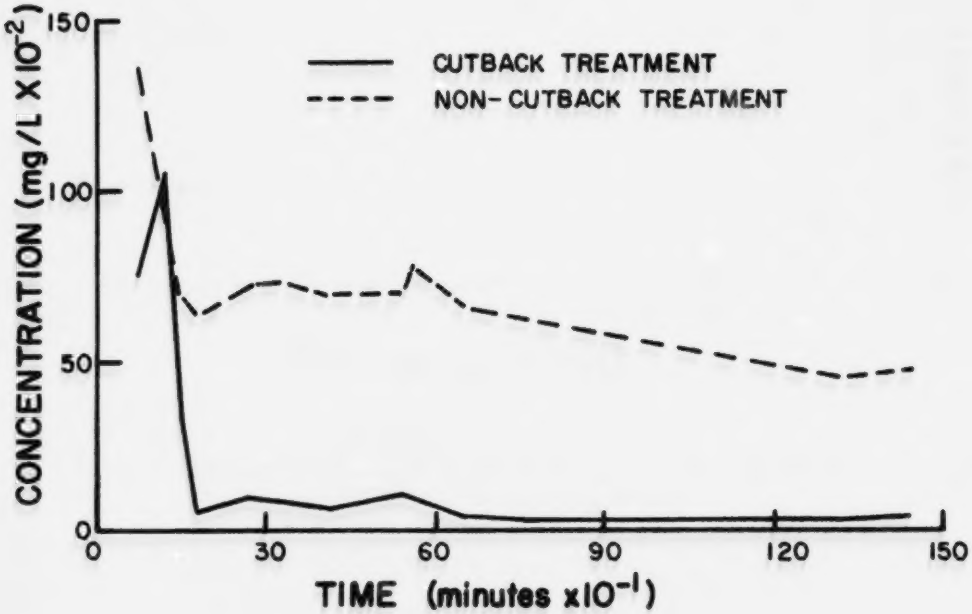


Figure 11. Sediment concentration in the surface runoff from Site 9 during the second irrigation in 1976.

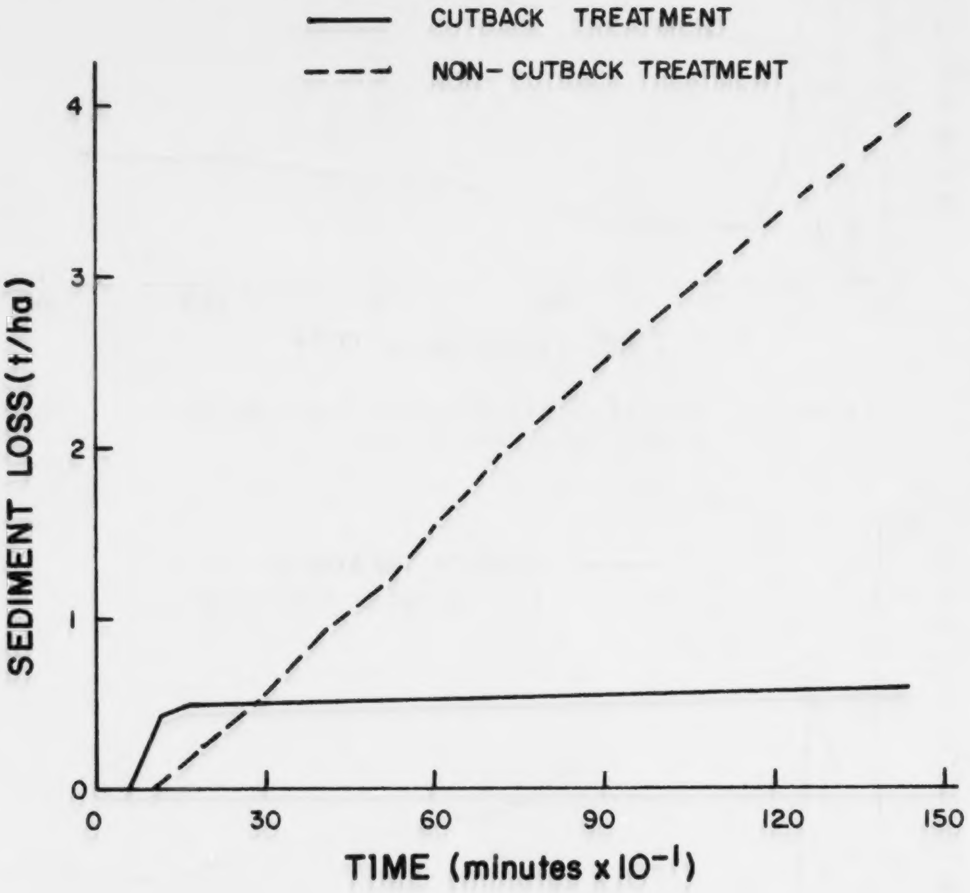


Figure 12. Sediment loss from Site 9 during the second irrigation in 1976.

TABLE 16. EFFECTS OF NUMBER OF IRRIGATIONS ON WATER AND SEDIMENT LOSSES

Year	Number of Irrigations	Consumptive Use (mm)	Water Applied (mm)	Water-Use[1] Efficiency (%)	Surface Runoff (mm)	Net Sediment Loss (kg/ha)
1975	8	510	1,270	40.1	376	26,565
1976	6	432	1,000	43.2	261	19,923

[1] Percentage of water applied going to consumptive use

operating under the soil, slope, run length, and other conditions present at this site. They could be increased by the installation and use of a pump-back system.

Preplant Irrigation

Many irrigators apply a preplant irrigation regardless of the soil moisture status. In order to evaluate the effects of this practice, preplant irrigations were applied to Sites 2, 3 and 4 ten days before the 1976 crop was planted. Water and sediment loss data for these irrigations are summarized in Table 17. The data show that a large amount of sediment was lost from each plot even though the runoff was not excessive. Over one-third of the seasonal sediment loss from Sites 2 and 3 occurred during the preplant irrigation. The amount of sediment lost from Site 4 during the preplant irrigation was nearly equal to the net amount retained on that plot during the remainder of the irrigation season (see Table 12). As a result, the loss during the preplant irrigation (1,188 kg/ha) was over fifteen times the net loss (76 kg/ha) from this site.

Tillage Practices

Compacted and Non-Compacted Furrows - In planting and cultivating fields in the Boise Valley, it is a common practice to compact every other furrow with planting and tillage equipment. The alternate furrows are never driven upon during the growing season and are, therefore, not compacted as much as the other furrows. This difference in compaction can greatly affect the rates of infiltration and runoff from alternate furrows.

In 1975, tests were conducted on Sites 2, 3 and 4 during the last three irrigations to determine differences in infiltration, runoff and sediment losses from alternate non-compacted furrows compared with compacted furrows. The results of this study are summarized in Table 18. As can be seen, there was essentially no runoff from the non-compacted furrows while 43 percent of the applied water ran off the compacted furrows. Due to the minimal amount of runoff, there was actually a net sediment gain in the non-compacted furrows.

Although the runoff and sediment losses from the non-compacted furrows were minimal, high infiltration rates in these furrows resulted in excessive

TABLE 17. EFFECTS OF PREPLANT IRRIGATIONS ON WATER AND SEDIMENT LOSSES, 1976

	Water Runoff		Net Sediment Loss		
Site	Preplant Irrigation (mm)	Percent of Seasonal Runoff	Preplant Irrigation (kg/ha)	Seasonal[1] Loss (kg/ha)	Percent of Seasonal Loss
2	41	16	1,773	5,031	35
3	52	23	1,657	4,450	37
4	69	36	1,188	76	1,563

[1] Seasonal total includes preplant irrigation loss

TABLE 18. COMPARATIVE RESULTS OF IRRIGATING ALTERNATE COMPACTED AND NON-COMPACTED FURROWS, 1975

Furrow Type	Water Applied (mm)	Surface Runoff (%)	Net Sediment Loss (kg/ha)
Compacted[1]	76	43	179
Non-Compacted[2]	132	6	-111[3]

[1] Values given are averages for four irrigation sets
[2] Values given are averages for five irrigation sets
[3] Negative number indicates a net gain

amounts of deep percolation and a low water distribution efficiency. Approximately 38 percent of the water applied in the non-compacted furrows was lost to deep percolation. Soluble nutrients were undoubtedly carried below the root zone by this water. The rate of advance in many of the non-compacted furrows was so low that the water did not reach the ends of the furrows during an irrigation set.

Number of Operations - Of all the sites studied in 1975 and 1976, only four were tilled following the first irrigation. Site 1 was tilled once following the first irrigation in both 1975 and 1976. Site 5 was tilled after both the first and second irrigations in 1975 and after the first three irrigations in 1976.

The additional tillage operations did not significantly increase the amount of sediment lost from Site 5. In 1975, the amount of sediment lost during the fifth and last irrigation was twice as great as that lost during any one of the first four irrigations. In 1976, the largest loss occurred during the fourth of five irrigations.

The sediment loss from Sites 2, 3 and 4, where the soil and slope were similar to the soil and slope at Site 1, decreased after the first irrigation. This difference may be attributed to the fact that Sites 2, 3 and 4 received no tillage following the first irrigation. The reason that additional tillage had a negative effect on Site 1 and not on Site 5 may be attributed to differences in soils and slopes at the two sites (see Tables 9 and 10).

Type of Tillage Equipment - Different types of tillage equipment were used in forming furrows in the seed alfalfa field (Site 6) during the two study years. In 1975, a common ditcher shovel was used to form the furrows. In 1976, a power-driven rotary-type tiller with v-shaped packer wheels was used. Comparisons of the 1975 and 1976 data show that the average sediment concentrations decreased from 2,845 mg/l to 1,278 mg/l for the first irrigation and from 2,173 mg/l to 979 mg/l for the second irrigation. The 1976 concentrations were 45 percent of the 1975 concentrations for both irrigations. This difference indicates that the furrows formed with the packer wheels were more stable and erosion resistant than those formed with the ditcher shovel.

Crops

The results presented thus far show that management practices associated with different crops affected sediment and other pollutant losses from the study sites. The concentrations and amounts of pollutants lost from Sites 1 through 8 during the 1975 and 1976 growing seasons are summarized by crop in Tables 19 and 20. The values given are averages for all fields for each crop. In some cases, the range of values is quite large.

The data in Table 19 indicate that the average concentrations of nitrate and ammonia nitrogen and soluble phosphorus in the runoff from all sites are quite low. The higher values for organic nitrogen and total phosphorus may be due to the fact that losses of these constituents are associated with sediment losses. Sediment concentrations and losses point to the fact that sediment is the main pollutant in the runoff leaving irrigated fields in the Boise Valley. Although the average concentration of the sediment in the runoff leaving the hop fields was less than that in the runoff from the barley fields, the net loss was greater due to more surface runoff from the hops.

The effects of different crops on adjacent fields and of different crops on the same fields were studied at Sites 6, 7 and 8. In 1975, the crops grown at the three sites were seed alfalfa, barley and sugarbeets. Average concentrations and net loss of nitrate-nitrogen, total phosphorus and sediment from the three sites are tabulated in Tables 21 and 22. The large net loss of sediment from the sugarbeet field can be attributed to the large amount of water lost to surface runoff from that field, a management practice which is related to a particular crop.

After the barley was harvested from Site 7 in 1975, a crop of seed alfalfa was established on this site. Barley was planted on Site 8 in 1975. The data in Table 23 show that the amount of water applied to Site 7 increased in 1976 as did the amounts of surface runoff and pollutants lost.

TABLE 19. AVERAGE CONCENTRATIONS OF POLLUTANTS IN THE SURFACE RUNOFF FROM SITES 1 THROUGH 8, 1975 and 1976

Crop	Number of Fields	Nitrate Nitrogen (mg/l)	Ammonia Nitrogen (mg/l)	Organic Nitrogen (mg/l)	Soluble Phosphorus (mg/l)	Total Phosphorus (mg/l)	Sediment (mg/l)
Corn	8	1.34	0.08	5.16	0.10	2.53	4,006
Sugarbeets	1	0.89	0.05	3.31	0.16	3.60	2,412
Barley	2	0.82	0.04	2.90	0.16	1.63	2,393
Hops	2	0.38	0.07	3.52	0.38	1.97	1,757
Seed Alfalfa	3	0.20	0.04	2.05	0.09	1.28	1,533
Averages for each Pollutant		1.02	0.07	4.33	0.15	2.39	3,193

TABLE 20. AVERAGE NET LOSSES OF POLLUTANTS FROM SITES 1 THROUGH 8, 1975 AND 1976

Crop	Number of Fields	Nitrate-Nitrogen (kg/ha)	Ammonia Nitrogen (kg/ha)	Organic Nitrogen (kg/ha)	Soluble Phosphorus (kg/ha)	Total Phosphorus (kg/ha)	Sediment (kg/ha)
Corn	8	7.87	-0.29[1]	8.42	0.10	6.37	8,132
Sugarbeets	1	-3.59	-0.37	-3.17	-0.16	9.63	6,636
Barley	2	0.01	-0.07	-1.09	-0.02	0.45	1,819
Hops	2	-0.30	0.10	4.65	0.27	0.86	4,403
Seed Alfalfa	3	-0.54	-0.08	-1.17	-0.11	0.35	1,228
Averages for each pollutant		3.56	-0.17	4.28	-0.05	4.00	5,489

[1] Negative numbers indicate net gains

TABLE 21. AVERAGE CONCENTRATIONS OF POLLUTANTS IN THE SURFACE RUNOFF FROM SITES 6, 7 AND 8, 1975

Site	Crop	Nitrate-Nitrogen (mg/l)	Total Phosphorus (mg/l)	Sediment (mg/l)
6	Seed Alfalfa	0.47	1.37	1,534
7	Barley	0.64	2.31	2,408
8	Sugarbeets	0.90	3.63	2,433

TABLE 22. FLOW AND POLLUTANT LOSS DATA FOR SITES 6, 7 AND 8, 1975[1]

Site	Crop	Water Applied (mm)	Surface Runoff (%)	Nitrate-Nitrogen Loss (kg/ha)	Total Phosphorus Loss (kg/ha)	Sediment Loss (kg/ha)
6	Seed Alfalfa	455	18	-1.50[2]	0.59	926
7	Barley	385	18	-1.08	0.37	1,142
8	Sugarbeets	1,235	27	-3.59	9.63	6,691

[1] Pollutant loss values are net values
[2] Negative numbers indicate net gains

TABLE 23. COMPARATIVE FLOW AND POLLUTANT LOSS DATA FOR SITES 7 AND 8, 1975 AND 1976[1]

Site	Year	Crop	Water Applied (mm)	Surface Runoff (%)	Nitrate-Nitrogen Loss (kg/ha)	Total Phosphorus Loss (kg/ha)	Sediment Loss (kg/ha)
7	1975	Barley	385	18	-1.08[2]	0.37	1,142
7	1976	Seed Alfalfa	557	18	0.01	0.85	1,619
8	1975	Sugarbeets	1,235	27	-3.59	9.63	6,691
8	1976	Barley	672	20	1.11	0.54	2,496

[1] Pollutant loss values are net values
[2] Negative numbers indicate net gains

Except for nitrate-nitrogen, the converse was true for Site 8.

SEDIMENT RETENTION DEVICES

Vegetated buffer strips and/or sediment retention ponds were installed at the lower ends of Sites 1 through 8. These devices were evaluated in conjunction with evaluations of the management practices used at these sites. Two large sediment ponds located in major wasteways were also evaluated. These evaluations are discussed in the following paragraphs.

Vegetated Buffer Strips

In 1975, a sodded grass strip which was 1.83 m wide and 61.0 m long was laid in the drainge ditch at the lower end of Site 3 as shown in Figure 13. The runoff from Site 3 entered the strip from the side while that from Site 4 entered the strip from the upper end and ran the entire length of the strip. Samples of the runoff from both sites were collected downstream from the strip. The runoff from the control plot, Site 2, did not run through the strip.

Dense bluegrass in the strip was well established and approximately 15 cm high just prior to the first irrigation. The strip did an excellent job of reducing the velocity of flow in the drain ditch during the first irrigation. As a result, it was completely inundated with sediment and was not effective during the remainder of the irrigation season. The effectiveness of the strip during the first irrigation is shown by the data in Table 24. About 47 percent of the net seasonal sediment loss from Site 2 (without strip) occurred during the first irrigation; whereas, only about 19 and 8 percent of the losses from Sites 3 and 4 (with strip), respectively, occurred during the first irrigation. Due to the ineffectiveness of the grassed strip, the net losses during the last four irrigations were essentially the same for all three sites.

In 1976, a 2.44 m wide strip of barley was seeded across the lower ends of the three plots at a seeding rate of approximately 100 kg/ha. The grain was well established when the irrigation season was started and was effective in retarding the furrow runoff and causing sediment to settle out of the runoff before it entered the drain ditch running parallel to the strip. Pictures of the strip following the first irrigation and midway through the irrigation season are shown in Figures 14 and 15, respectively. Sediment retained by the strip is shown in Figure 16. The effectiveness of this strip is shown by the data presented in Table 24. Site 2 was irrigated nearly the same in 1976 as it was in 1975. Most of the difference in the total net sediment loss (3258 kg/ha in 1976 as opposed to 7038 kg/ha in 1975) can be attributed to the effect of the buffer strip used in 1976. Although the net loss from Site 2 during the first irrigation in 1976 was nearly as great as the loss during the first irrigation in 1975, use of the grain strip resulted in a marked decrease in the net sediment losses during the last four irrigations. The data in Table 24 indicate that the grain strip used in 1976 was more effective than the grassed strips used on Sites 3 and 4 in 1975.

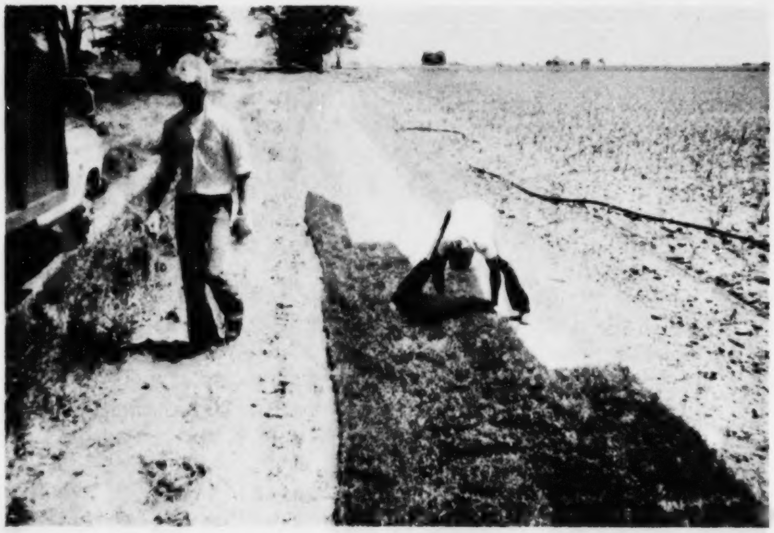


Figure 13. Sod buffer strip being installed in 1975.

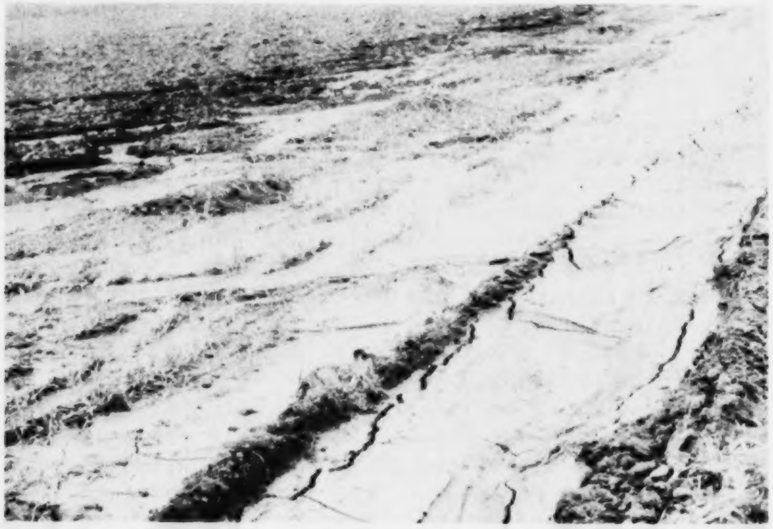


Figure 14. Grain buffer strip following the first irrigation in 1976.

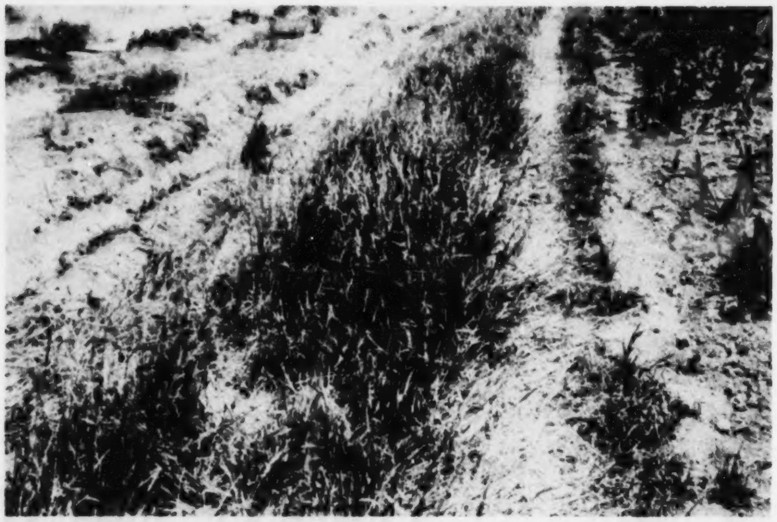


Figure 15. Grain buffer strip midway through the 1976 irrigation season.

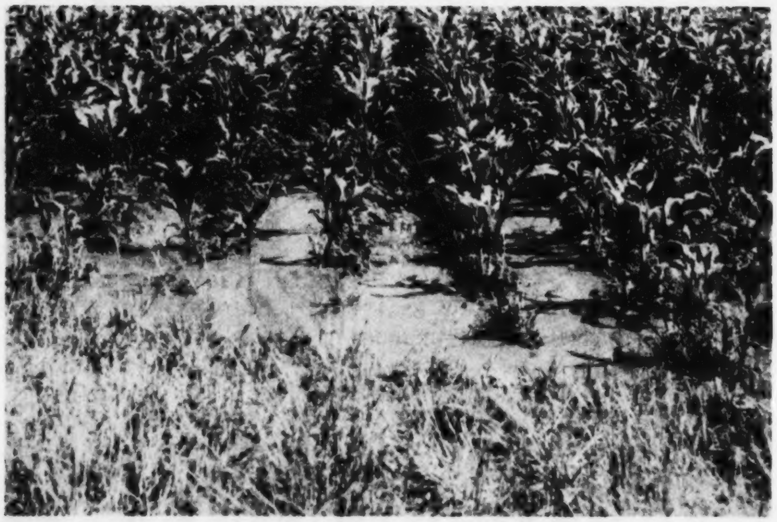


Figure 16. Sediment deposited from furrow runoff backed up by grain buffer strip in 1976.

TABLE 24. EFFECTS OF VEGETATED BUFFER STRIPS ON SEDIMENT LOSSES

Site	Year	Strip Type	Irrigation Number(s)	Net Sediment Loss (kg/ha)
2	1975	none	1	3,312
			2-5	3,726
			total	7,038
3	1975	grass	1	740
			2-5	3,149
			total	3,889
4	1975	grass	1	367
			2-5	4,196
			total	4,563
2	1976	grain	1	2,456
			2-5	802
			total	3,258

Sediment Retention Ponds

Sediment retention ponds were used to remove a portion of the sediment and phosphorus from the surface runoff from the study sites. In 1976, six small T-shaped basins (T-slots) similar to the one shown in Figure 17 were also installed at intervals of about 20 meters in the drain ditch upstream from the sediment pond at Site 1. The T-slots were dug with a backhoe with the top of the "T" perpendicular to the drain ditch. Four of the T-slots had a capacity of approximately 2 m^3 while the other two had a capacity of about 0.5 m^3. The six T-slots were filled with sediment during the first irrigation (Figure 18) and were ineffective thereafter. The effectiveness of the T-slots and pond during the first irrigation is shown by the data presented in Table 25.

The sediment retention ponds were quite effective in reducing the net sediment losses from the study sites. Seasonal sediment balances for the field sites and ponds are given in Table 26. The sediment removal efficiency of the ponds ranged from 40 to 82 percent. One reason for the low removal efficiency of the pond at Site 1 in 1975 was the small size of this pond. It was essentially filled with sediment by the first two irrigations in 1975. With the added retention of the T-slots in 1976, the pond did not fill with sediment until after the third irrigation. Pictures of the pond prior to and after the third irrigation in 1976 are shown in Figures 19 and 20, respectively. Even though the pond was ineffective for over half of the irrigation season each year, it did greatly reduce the sediment loss from this site.

All of the runoff from Sites 2, 3 and 4 was diverted through the same pond. The data in Table 26 show that the sediment removal efficiency of this

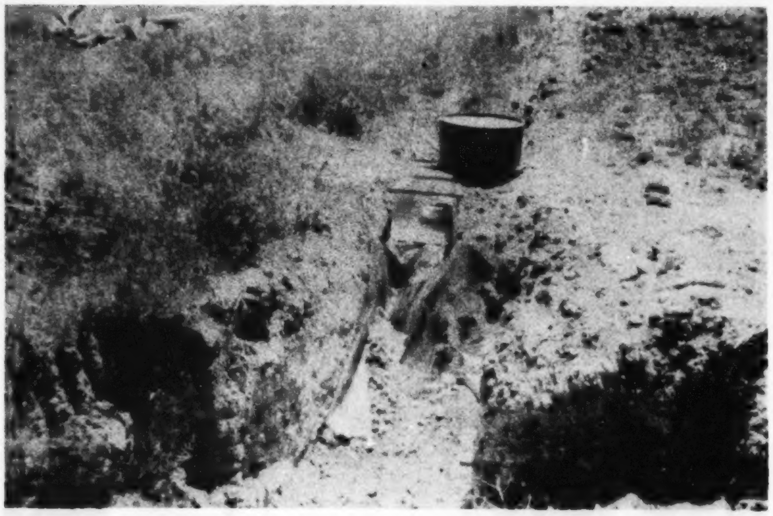


Figure 17. T-slot prior to the first irrigation of Site 1 in 1976.

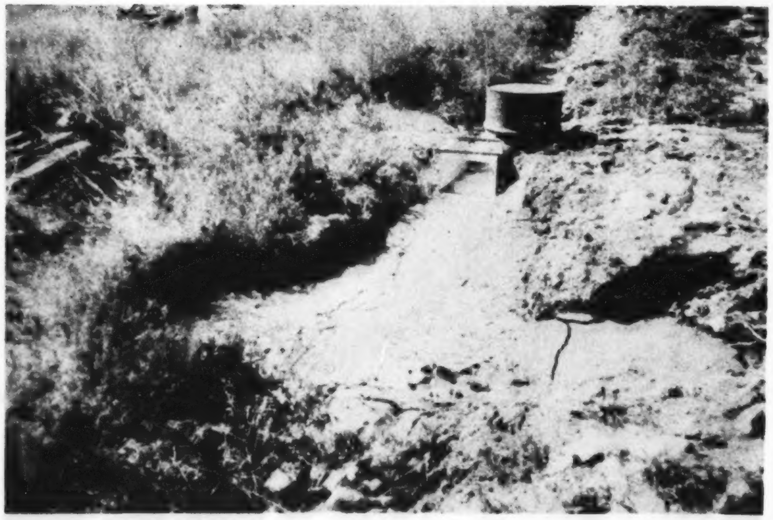


Figure 18. T-slot after the first irrigation of Site 1 in 1976.

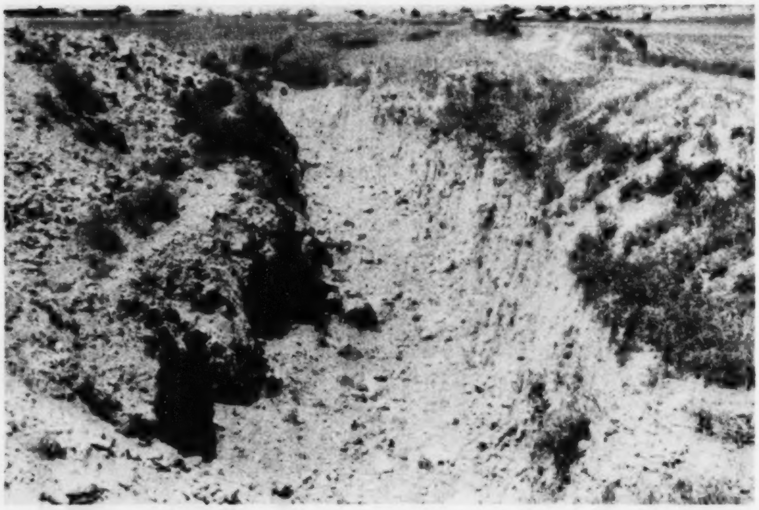


Figure 19. Sediment pond at Site 1 prior to the first irrigation in 1976.

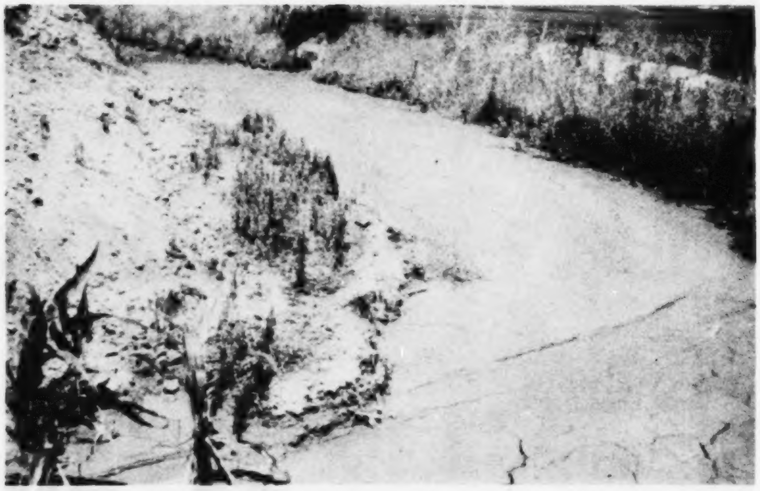


Figure 20. Sediment pond at Site 1 after the third irrigation in 1976.

TABLE 25. SEDIMENT AND PHOSPHORUS REMOVAL BY T-SLOTS AND SEDIMENT POND AT SITE 1 DURING THE FIRST IRRIGATION, 1976

Constituent	Into T-Slots (kg/ha)	Into Pond (kg/ha)	Out of Pond (kg/ha)	Removal by T-Slots (%)	Removal by T-Slots and Pond (kg/ha)
Total Phosphorus	0.73	0.33	0.24	45	78
Sediment	1055	504	189	48	66

pond was quite high both years. This pond was large enough that it did not require cleaning after the 1975 season and was only about half filled with sediment at the end of the 1976 season.

During both irrigation seasons, the pond installed at Site 5 removed 64 percent of the sediment from the runoff from the hop field at this site. This pond was adequately sized so that it too was only about half filled with sediment after two seasons of use. Another problem with hop fields is that a considerable amount of floating residue is sometimes carried in the runoff. A screen installed at the outlet of the pond, as shown in Figure 21, was effective in filtering floating material from the runoff. Downstream irrigators, who reuse the runoff from this field, commented on the improvement in the quality of the runoff after the screen was installed.

A single pond was used for removing sediment from the runoff from Sites 6, 7 and 8. Water entered each end of the pond and was discharged through an outlet located near the center of one side of the pond (Figure 22). Since the outlet was in the center of the pond, the effective length of the pond was only half of its total length. The pond was smaller than the ponds at the other study sites; and, as a result, required cleaning at the end of each irrigation season. This pond, however, was as effective in removing sediment from runoff as the other two ponds.

The results obtained from these studies indicate that on-farm sediment retention ponds are effective in removing sediment even when they are partially filled with sediment. It is necessary that the velocity of the water moving through the pond be reduced enough to allow sediment to settle. A small pond, which is cleaned on an annual basis, has the greatest retention time during the first few irrigations when the sediment loads in the runoff are the largest.

Large Sediment Retention Ponds

The two large sediment ponds monitored in this study were located in natural drainageways near Wilder and Melba. Runoff from 325 hectares of land drain into the Wilder pond. In addition, operational waste from the end of a supply lateral flows into this pond. The water flowing into the Melba pond is diverted from a district canal. However, a large portion of the water conveyed by the canal at the diversion point is runoff from higher lands which

TABLE 26. SEASONAL SEDIMENT BALANCES FOR THE BOISE VALLEY ON-FARM SITES AND SEDIMENT PONDS, 1975 AND 1976

						Net Loss	
Site	Year	On Plots (kg/ha)	Off Plots[1] (kg/ha)	Out of Pond (kg/ha)	Removal by Pond (%)	w/o Pond (kg/ha)	with Pond (kg/ha)
1	1975	621	27,146	14,710	46	26,525	14,089
	1976	482	20,405	6,273	69	19,923	5,791
2	1975	1,051	8,088	1,425	82	7,038	374
	1976	1,004	4,262[2]	770	82	3,258	-234[3]
3	1975	1,352	5,241	934	82	3,889	-418
	1976	775	3,568[2]	888	75	2,793	113
4	1975	1,652	6,215	1,232	80	4,563	-420
	1976	1,787	675[2]	261	61	-1,112	-1,526
5	1975	306	5,256	1,864	64	4,950	1,558
	1976	302	4,158	1,478	64	3,856	1,176
6	1975	365	1,291	453	65	926	88
	1976	693	614	368	40	-79	-325
7	1975	501	1,643	338	79	1,142	-163
	1976	553	2,172	655	70	1,619	102
8	1975	1,303	7,994	2,184	73	6,691	881
	1976	742	3,238	951	71	2,496	209

[1] Includes effects of T-slots and vegetated buffer strips where used on Sites 1, 2, 3 and 4

[2] Does not include preplant irrigation

[3] Negative numbers indicate a net gain

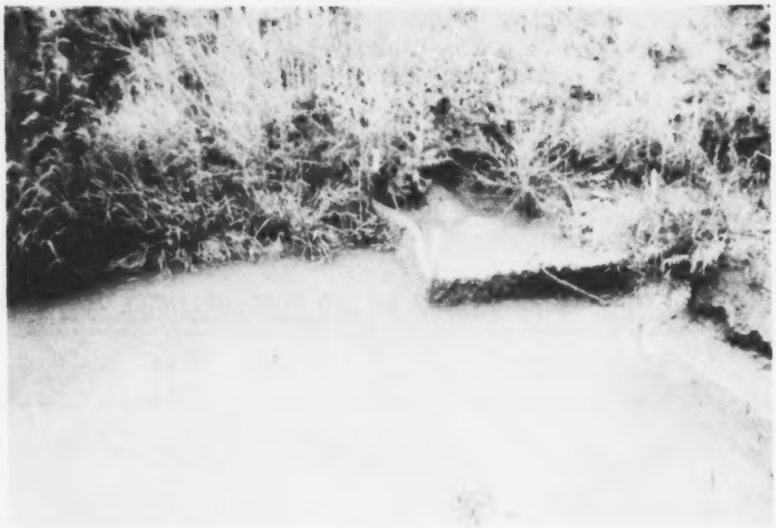


Figure 21. Screen for retaining floating debris in the sediment pond at Site 5.

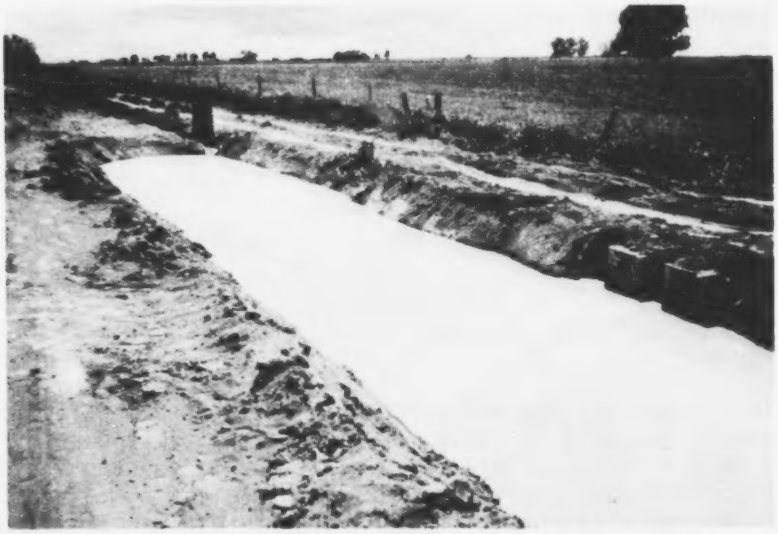


Figure 22. Side-outlet pond used to remove sediment from the runoff from Sites 6, 7 and 8.

has been collected for reuse on lower lands.

The area draining into the Wilder pond is an intensively farmed area, as shown by the crop data in Table 27. The average flow rate into the pond was approximately 0.25 cubic meters per second (m^3/sec), and the sediment yield from the drainage area averaged approximately 5 metric tons/hectare (t/ha). The canal diverted through the Melba pond had an average flow rate of about 0.55 m^3/sec. Return flows entering the canal were from an intensively cropped area which is similar to the area draining into the Wilder pond except that hops are not grown in this area.

TABLE 27. CROPS GROWN IN THE WILDER POND DRAINAGE AREA, 1976

Crop	Area (ha)
Alfalfa Hay	9
Alfalfa Seed	2
Barley	29
Dry Beans	7
Sugarbeets	86
Corn	4
Potatoes	38
Hops	87
Onions	37
Orchard	9
Pasture	17
Total	325

The effectiveness of the two ponds in removing sediment and other pollutants is shown by the data in Table 28. The main differences in the removal efficiencies of the two ponds are for ammonia and sediment. The differences in ammonia concentrations and removal efficiencies may be attributed to the fact that considerable amounts of fertilizer were applied by side dressing during June and July in the Wilder area. The sizing of the ponds affected their sediment removal efficiencies. Although the average flow rate through the Melba pond was more than twice that through the Wilder pond, the capacity of the Melba pond was only half that of the Wilder pond (1,500 m^3 versus

3,000 m^3). As shown in Figure 23, the Melba pond was essentially filled with sediment by August 20 during both years. Even so, more than 1,200 metric tons of sediment were removed each year from the water flowing through this pond. This essentially eliminated downstream canal cleaning operations which were previously necessary. Sediment cleaned from both ponds was used by the irrigation district for canal maintenance.

TABLE 28. AVERAGE POLLUTANT CONCENTRATIONS AND REMOVAL EFFICIENCIES FOR LARGE SEDIMENT RETENTION PONDS, 1975 AND 1976

	Wilder Pond			Melba Pond		
	Concentration		Removal	Concentration		Removal
Constituent	In (mg/l)	Out (mg/l)	Efficiency (%)	In (mg/l)	Out (mg/l)	Efficiency (%)
Nitrate Nitrogen	0.870	0.836	4	0.474	0.451	5
Ammonia Nitrogen	0.861	0.491	40	0.523	0.514	2
Organic Nitrogen	2.00	1.51	24	1.27	0.879	31
Soluble Phosphorus	0.113	0.106	6	0.113	0.103	9
Total Phosphorus	0.610	0.440	27	0.405	0.332	18
Sediment	852	297	65	390	235	40

The average concentrations of the pollutants entering and leaving the large sediment ponds were generally less than those for the smaller on-farm ponds monitored in this study. The data in Table 29 indicate that ammonia is the only exception. The average sediment concentrations in the flows entering and leaving the large ponds were about one-fifth those for the smaller ponds. This was due to the fact that much of the sediment in the surface runoff from fields in the drainage areas served by the large ponds settled out in the drainageways before it reached the ponds. Consequently, the concentrations of the materials associated with sediment were also reduced in the flows entering and leaving the large ponds. The average removal efficiencies of the on-farm ponds were higher than those for the large ponds for all constitutents analyzed.

SUMMARY

Several of the management practices evaluated in the Boise Valley during the 1975 and 1976 irrigation seasons were found to be effective in reducing

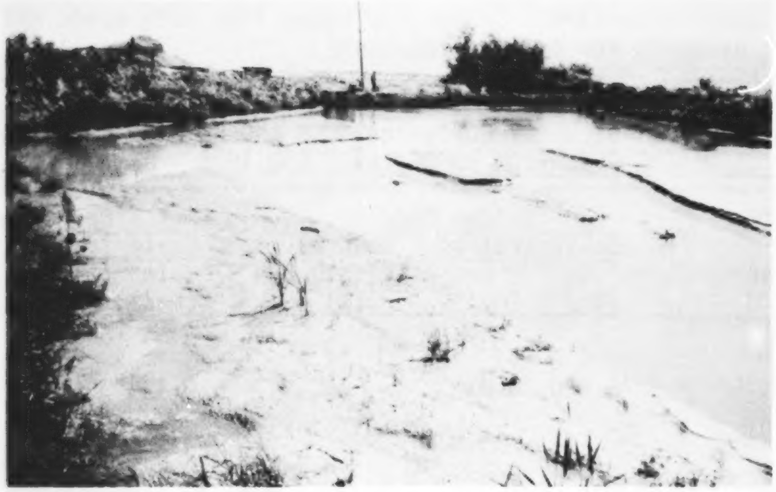


Figure 23. Large sediment pond near Melba, Idaho showing the sediment accumulation late in the irrigation season.

TABLE 29. AVERAGE POLLUTANT CONCENTRATIONS AND REMOVAL EFFICIENCIES FOR LARGE AND ON-FARM SEDIMENT RETENTION PONDS, 1975 AND 1976

Constituent	Large Ponds			On-Farm Ponds		
	Concentration		Removal Efficiency (%)	Concentration		Removal Efficiency (%)
	In (mg/l)	Out (mg/l)		In (mg/l)	Out (mg/l)	
Nitrate Nitrogen	0.594	0.568	4	1.02	0.96	6
Ammonia Nitrogen	0.562	0.507	10	0.066	0.058	12
Organic Nitrogen	1.49	1.07	28	4.32	1.88	57
Soluble Phosphorus	0.113	0.104	8	0.153	0.128	16
Total Phosphorus	0.468	0.367	22	2.37	0.96	59
Sediment	530	254	52	3,162	1,052	67

sediment and nutrient losses from surface-irrigated fields. Sediment retention devices were also found to be effective in reducing the amounts of sediment and certain nutrients lost from individual fields as well as large irrigated areas.

Furrow stream size was found to have a direct influence on the amounts of sediment and nutrients lost from irrigated fields. On adjacent plots planted to field corn, the use of a furrow stream size of 0.77 l/s during the first three irrigations resulted in a net sediment loss of 3,258 kg/ha; whereas, the use of a furrow stream size of approximately 0.4 l/s resulted in a net sediment gain of 1,112 kg/ha. There was a net loss of total phosphorus (1.52 kg/ha) from the plot where the larger furrow stream size was used and a net gain (0.48 kg/ha) on the other plot. There was a net gain of nitrate nitrogen on both plots. These results indicate that it may be possible to completely eliminate sediment and nutrient losses from furrow-irrigated fields by using the proper furrow stream size.

Cutting furrow flows back after they reach the end of a field increases the efficiency of water-use and reduces sediment losses. Conventional irrigation of a plot planted to field corn resulted in a water-use efficiency of 41 percent and a net sediment loss of 13,534 kg/ha. Cutback irrigation on an adjacent field corn plot resulted in a water-use efficiency of 78 percent and a net sediment loss of only 915 kg/ha. In this case, cutting the furrow flows back resulted in a large increase in the amount of water saved and a 93 percent reduction in the net amount of sediment lost. A similar reduction was found in the net amount of phosphorus lost from the cutback-irrigated plot.

The timing of irrigations was found to influence sediment and nutrient losses from surface-irrigated fields. Reducing the number of irrigations on one study site from eight in 1975 to six in 1976 resulted in a 21 percent reduction in the amount of water applied and a 25 percent reduction in the amount of sediment lost from the study site. Preplant irrigations may result in heavy sediment losses. Over one-third of the seasonal sediment loss from three sites monitored in this study occurred during preplant irrigations.

Tillage practices can have a marked effect on water-use efficiencies and sediment and nutrient losses. Irrigating in compacted furrows resulted in more surface runoff and greater sediment losses than irrigating in non-compacted furrows. However, high infiltration rates in the non-compacted furrows resulted in excessive deep percolation losses and poor water distribution efficiencies for these furrows. The number of tillage operations during the irrigation season did not greatly affect sediment losses from a hop field on a 1.1 percent slope. This was not the case, however, for a corn field on a 2.6 percent slope. Tilling this field between the first and second irrigations caused the sediment loss to more than double (from 5,291 kg/ha to 12,705 kg/ha). In contrast, the sediment loss from corn fields which were not cultivated after the first irrigation decreased.

Vegetated buffer strips can be used to retard the runoff from furrow-irrigated fields and thereby cause some of the sediment carried by the runoff to be settled out. Evaluations of a sodded grass strip in 1975 and a grain (barley) strip in 1976 show that each type of strip removed about 45 percent of the sediment from the runoff passing through the strips. The grass strip was more effective than the grain strip during the first irrigation; whereas, the grain strip was more effective during later irrigations.

On-farm sediment ponds were found to be effective in removing from 40 to 82 percent of the sediment from flows entering the ponds. The variation in the removal efficiency of the ponds was due to several factors, including the size of the ponds and the quality of the water entering the ponds. Sediment-laden water entering one small on-farm pond filled the pond with sediment after only two irrigations. As a result, the sediment-removal efficiency of this pond was only 40 percent. Properly sized ponds, on the other hand, removed over 70 percent of the sediment from incoming runoff and were only half filled with sediment after two years of use.

Large sediment retention ponds located in natural drainageways can be used to remove sediment and nutrients from return flows from large irrigated areas. The results obtained from monitoring two large ponds in the Boise Valley show that the sediment removal efficiencies of these two ponds were 40 and 65 percent, respectively. Approximately 20 percent of the total phsophorus and 30 percent of the organic nitrogen entering these ponds was removed. Overall, the large ponds were not as effective in removing sediment and nutrients as smaller on-farm ponds. This is due, at least in part, to the fact that much of the sediment and other materials in the runoff from surface-irrigated fields settles out in the drainageways before it reaches the large ponds.

In summary, it may be stated that water, sediment and nutrient losses from surface-irrigated fields can be greatly reduced or even eliminated by integrating the use of proper management practices with the use of sediment retention devices. In this study, combining the use of improved water management practices with the use of vegetated buffer strips and sediment retention ponds resulted in net gains of sediment, total phosphorus and nitrate nitrogen on several of the study sites.

SECTION 7

MAGIC VALLEY FIELD INVESTIGATIONS

Field investigations of several management practices and sediment removal systems were conducted at sites near Kimberly in the Magic Valley. Included were on-farm studies of (1) tillage and other cultural practices, (2) mini-basins, (3) vegetated buffer strips, (4) sediment removal by a dense growing crop and (5) furrow cutback irrigation. In addition, large district-type sediment removal systems were also studied. Most of these studies were conducted at the Kimberly Research and Extension Center in cooperation with Agricultural Research Service personnel at the Snake River Conservation Research Center located at Kimberly, Idaho.

The on-farm experiments were conducted primarily to determine the effectiveness of different practices and systems in reducing water, sediment and phosphorus losses from irrigated fields. The district-type sediment removal systems were monitored to determine their effectiveness in removing sediment and phosphorus from return flows from large irrigated areas. Other nutrients, pesticides and chemical constituents were not considered in these studies.

TILLAGE STUDY

A 1.48-hectare field at the Kimberly Center was used to evaluate the effects of seedbed preparation and cultivation practices on water and sediment losses from a dry bean field in 1975 and 1976. The soil at this location is Portneuf silt loam with field slopes varying from 0.8 to 1.2 percent. Two methods of preplant irrigation were used to prepare the field for planting. In one case ("broadcast" procedure), a 76-cm furrow spacing was used to wet the entire field surface. In the other ("banded" procedure), a 122-cm furrow spacing was used to wet only the seedbed area. After the preplant irrigation, the plots were harrowed and planted with Pinto (UI114) bean seed in rows which were about 96 meters long. A row spacing of 122 centimeters was used and furrows were made in every other row during the planting process. A total of 30 plots were established in the field.

After planting, the two irrigation treatments were split into three cultivation treatments. Each treatment was replicated five times. In 1975, the two irrigation treatments received 1, 2 and 3 cultivations with a standard 4-row bean cultivator after emergence of the beans. In 1976, the irrigation treatments received 0, 1 and 2 cultivations. In 1975, eight irrigations at 8- to 12-day intervals were performed prior to harvest. The 1976 experiment was terminated after a hailstorm destroyed the crop during the sixth irrigation. Eight-hour sets were used during both years.

During each irrigation, the total flow onto the field was determined by measuring the difference in discharge between two weirs in the concrete-lined head ditch at the upper end of the field. One of these installations is shown in Figure 24. Siphon tubes from the head ditch were set as accurately as possible to obtain approximately equal flow in each furrow in 1975. In 1976, each tube was set with a leveling device to insure that the differential head between the ditch water surface and the end of each tube was exactly the same (Figure 25).

At the end of the field, two furrows were converged and 6.1 meters of 4 mil thick plastic was laid in the invert leading to a V-notch flume as shown in Figure 26. The plastic was used to prevent erosion on the lower ends of the furrows where the slope was significantly steeper than it was in the rest of the field. This condition of steeper slopes at the lower ends of fields (convex-end syndrome) is fairly common in the Magic Valley (Figure 27). The discharge was measured at intervals of 15, 30, 60 and 120 minutes until the end of each set. One-liter samples were taken from the outlet of the flumes at the same time intervals.

Sediment concentrations were determined by vacuum filtering the one liter samples through pre-dried Whatman No. 50, 24-cm diameter filter papers. The filters were dried and weighed and sediment concentrations determined. Flow data and sediment concentrations were used as input to a computer program for determination of the surface runoff and sediment yield from each plot for each irrigation.

Filtered and unfiltered phosphorus samples were taken at random furrow locations throughout each irrigation. Filtered samples were obtained in the field using vacuum filtration through 0.45 μm millipore filters. Filtered samples were analyzed for ortho and total phosphorus using methods described by Carter, et al. (1974). Filtered sediment from each sample was scraped from the filter paper and analyzed for total and bicarbonate extractable phosphorus. An analysis of variance on sediment yield was performed using slope, irrigation treatment, and cultivation treatment.

The results of the 1975 study show that there was no significant relationships between the number of cultivations and sediment losses. For the preplant irrigation, the banded application resulted in 25 percent less surface runoff than the broadcast application. The sediment yield from the banded treatment was lower than that from the broadcast treatment. The difference, however, was not significant. This lack of a significant difference in sediment yields between the two preplant treatments was attributed to variations in furrow flow which resulted from the way in which the siphon tubes were set. For this reason, the experiment was repeated in 1976 with more accurate control of the furrow stream size.

Sediment yield and surface runoff data for the 1976 study are given in Tables 30 and 31. The value given for each treatment is the average of five replications. Surface runoff, which should be influenced by furrow conditions at the inception of irrigation, was not significantly correlated with the number of cultivations. Significant differences in sediment yield did occur between the two preplant irrigation treatments. The yield from the broadcast treatment, for example, was 1,050 kg/ha while that from the banded

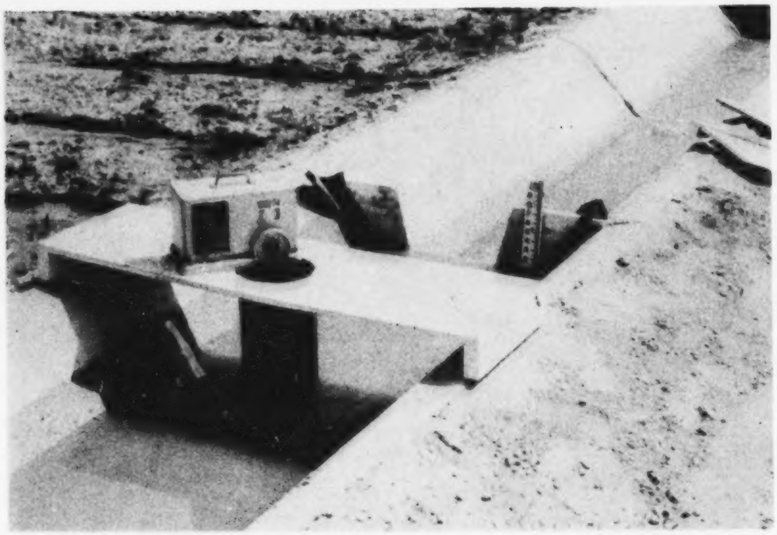


Figure 24. Weir and recorder used to measure the flow onto the bean tillage and mini-basin study sites in 1976.

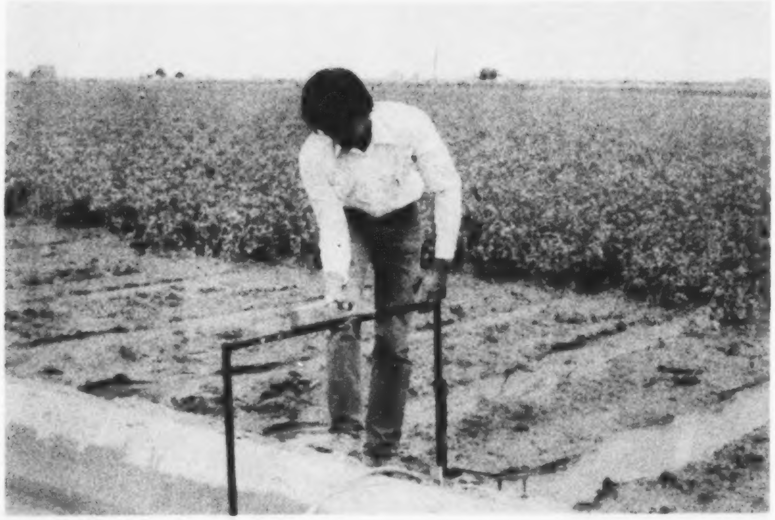


Figure 25. Leveling device used to set siphon tubes in the bean tillage and mini-basin studies in 1976.

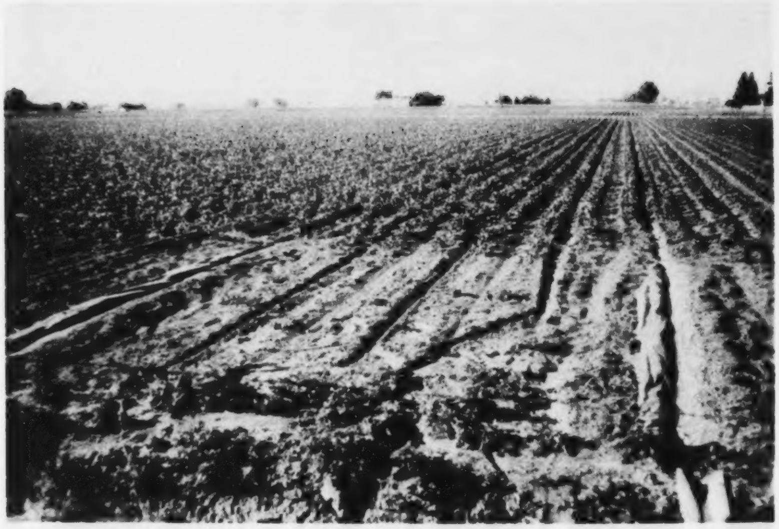


Figure 26. Lower end of the bean tillage study site showing plastic-lined furrows.

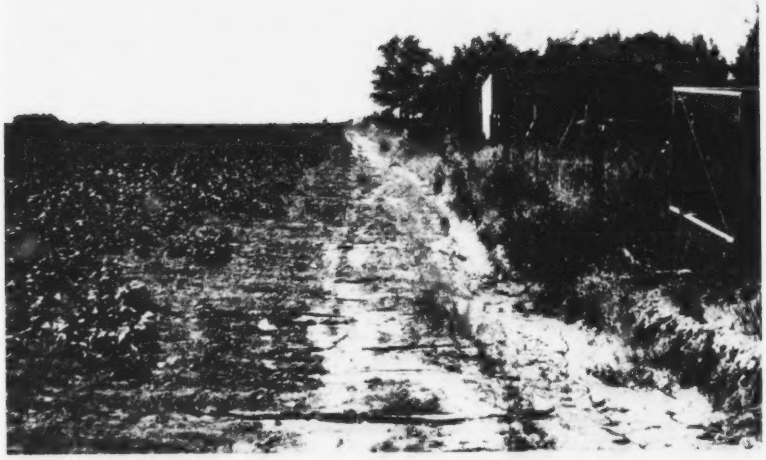


Figure 27. Lower end of a bean field showing the convex-end syndrome common in the Magic Valley.

TABLE 30. SURFACE RUNOFF DATA, 1976 MAGIC VALLEY BEAN TILLAGE STUDY

Irrigation Number		Surface Runoff (%) Cultivation Treatment 1	2	3	Average
1		18.6	16.5	18.2	17.8
2		35.1	37.1	33.7	35.3
3		42.1	39.5	36.2	39.3
4		46.4	49.2	39.2	44.9
5		40.3	42.1	40.0	40.8
	Average	36.5	36.9	33.5	35.6

TABLE 31. SEDIMENT YIELD DATA, 1976 MAGIC VALLEY BEAN TILLAGE STUDY

Irrigation Number		Sediment Yield (kg/ha) Cultivation Treatment 1	2	3	Average
1		623	716	619	653
2		1,296	1,280	1,209	1,261
3		2,675	2,165	1,812	2,217
4		2,064	2,334	1,646	2,015
5		1,532	2,053	2,469	2,018
	Totals	8,189	10,257	7,754	8,164

treatment was only 260 kg/ha. This difference is to be expected since the furrow spacing for the broadcast preplant irrigation was less than that for the banded preplant irrigation. For the same furrow flow, the runoff and resulting sediment loss per unit area would be greater for the broadcast treatment than for the banded treatment.

In 1975, 869 mm of water were applied to the bean field in eight irrigations. Approximately half (50.9 percent) of this water left the field as surface runoff. The sediment yield for the season was 28,530 kg/ha. The average discharge per siphon tube for all irrigations was 0.37 l/sec.

In 1976, 343 mm of water were applied during the first five irrigations. This represents approximately 60 percent of the amount of water that would have been applied in the normal eight irrigations if the experiment had been carried to completion. About one-third (35.6 percent) of the applied water left the field as surface runoff. The sediment yield for the field for the five irrigations was 8,164 kg/ha. The average siphon tube discharge was 0.28 l/sec.

The total sediment yield for the five irrigations in 1976 was less than one-third the yield in 1975. Based on the 1975 results, the expected yield in 1976 would have been nearly twice the measured yield. The decrease in yield can be explained by the decrease in furrow flow in 1976 and the corresponding decrease in surface runoff.

Phosphorus loss data for the 1976 study are given in Table 32. There is no significant difference in phosphorus losses due to cultivation treatments. The total phosphorus loss from the field amounted to 7.38 kg/ha.

TABLE 32. TOTAL PHOSPHORUS LOSS DATA, 1976 MAGIC VALLEY BEAN TILLAGE STUDY

Irrigation Number	Total Phosphorus Loss (kg/ha)			
	Cultivation Treatment			
	1	2	3	Average
1	0.44	0.50	0.44	0.46
2	1.11	1.18	1.01	1.10
3	2.47	2.05	1.81	2.11
4	1.85	2.21	1.63	1.90
5	1.34	1.80	2.28	1.80
Totals	7.21	7.75	7.17	7.38

The field slopes of the 30 tillage study plots varied from 0.78 to 1.2 percent. The results of the 1976 study show that field slope had a significant effect on sediment yield. This is shown by the regression equations and plots of field slope versus sediment yield presented in Figure 28. The units used for sediment yield in this figure are metric tons (tonnes) per hectare (t/ha). The data presented in this figure also indicate that the sediment yield increased as the season progressed on the steeper field slopes (1.2 percent) but stayed nearly the same on the flatter slopes (0.78 percent). Further experimentation is needed to determine whether these differences are significant.

Water retention (amount of water applied minus surface runoff) is also significantly affected by field slope as shown in Figure 29. Except for the fifth irrigation, the percentage of applied water retained on the field decreased as field slope increased. More water was retained during the preplant irrigation (Irrigation No. 1) for all slopes than was retained during any of the later irrigations. This was probably due to antecedent moisture conditions.

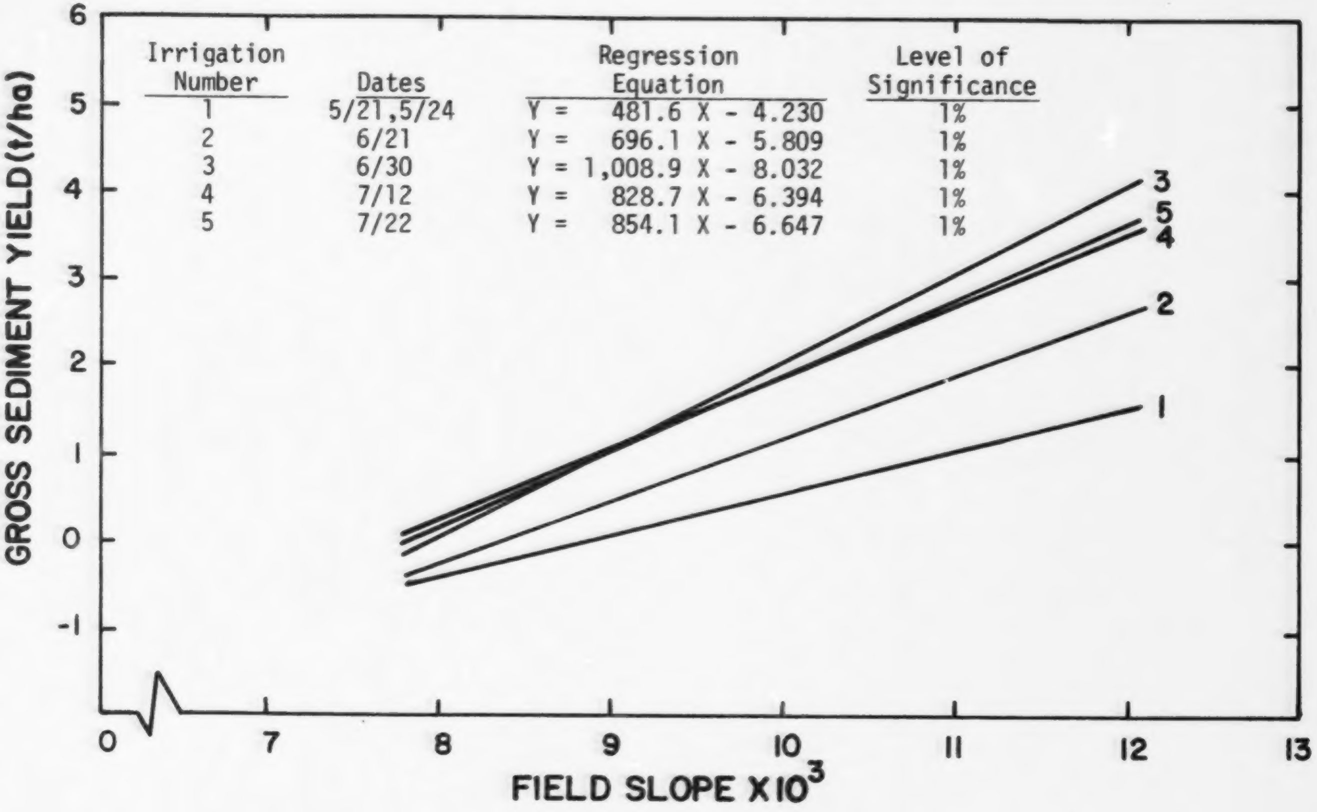
The results of both the 1975 and 1976 experiments indicate that there is a direct relationship between the seasonal gross sediment yield from the bean field and surface runoff. A plot of the gross sediment yield versus percent runoff for the 13 irrigations performed in 1975 and 1976 is shown in Figure 30. This relationship illustrates one of the basic concepts in reducing sediment losses from gravity-irrigated fields. Generally, any practice which will decrease the surface runoff will result in a decrease in sediment and phosphorus losses.

MINI-BASIN STUDY

In 1976, a mini-basin study was conducted on a 1.38-hectare bean field adjacent to the tillage study field. The field was preplant irrigated, harrowed and planted to Pinto (UI114) beans. The beans received three cultivations after emergence. A total of 12 basins were installed by constructing berms perpendicular to the bank of the drain ditch along the lower end of this field to form small shallow ponds abutting the drain ditch bank (Figure 31). The basins were constructed to collect flow from 3, 4 and 5 furrows and with either a plastic overflow section on the ditch bank or a grassed overflow section. Several of basins with grassed overflow sections are shown in Figure 32. The overflow sections were 0.5 meters wide and were leveled to provide uniform flow over the section. Bluegrass sod was transplanted onto the overflow section prior to the first irrigation.

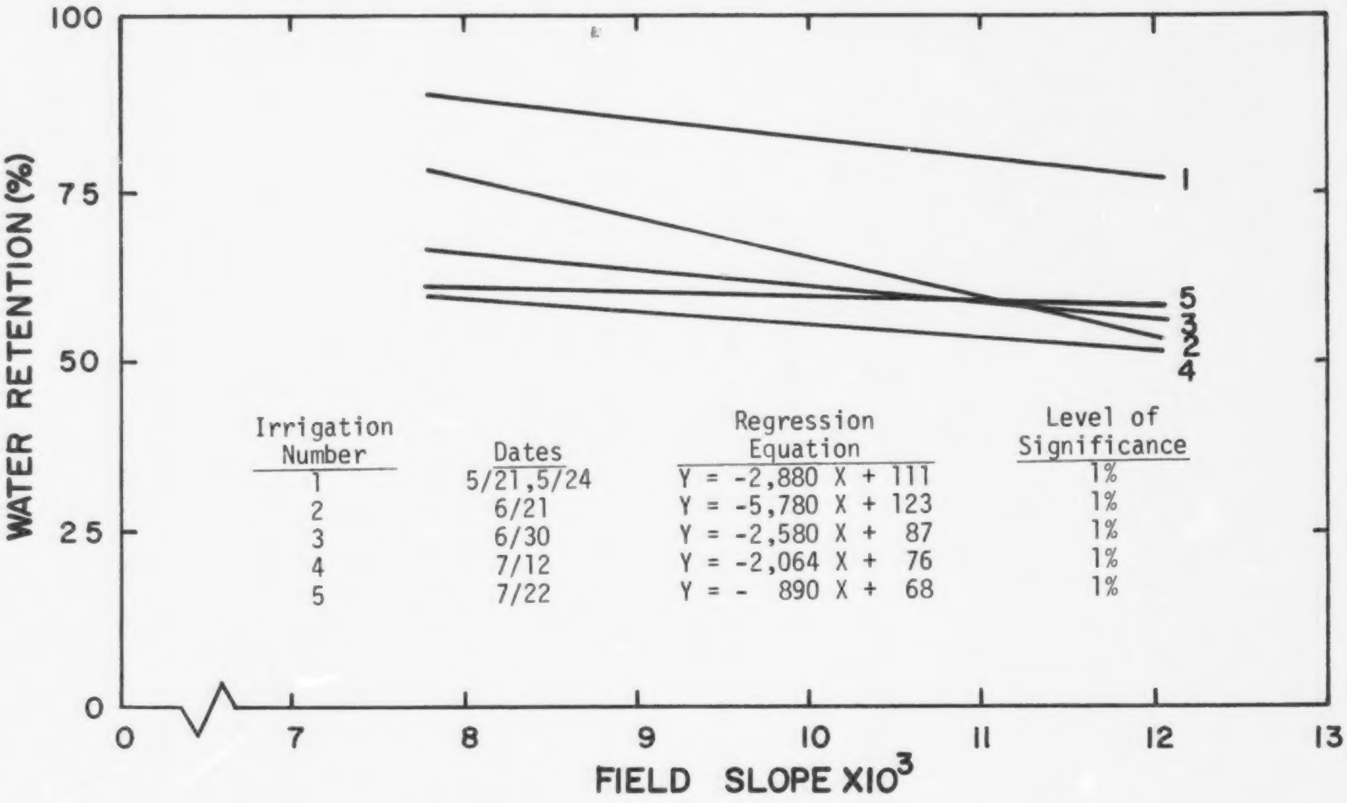
A V-notch flume was installed between each mini-basin as shown in Figure 33 to collect and measure the flow from two check furrows. Plastic was laid in the furrows for a distance of 6.1 meters upstream from the flume to eliminate erosion in the lower part of furrows.

Siphon tubes were set and flows were sampled and measured in the same way as in the tillage study. One-liter samples were obtained from the outlet of the mini-basins by integrating the collection along a board installed as shown in Figure 32 along the downstream side of the overflow sections. Since the flow from the basins could not be measured, it was assumed that the unit furrow flow from the basin was the average of the unit furrow flows of the check furrows on each side of the basin at the same time.



Irrigation Number	Dates	Regression Equation	Level of Significance
1	5/21,5/24	$Y = 481.6\ X - 4.230$	1%
2	6/21	$Y = 696.1\ X - 5.809$	1%
3	6/30	$Y = 1{,}008.9\ X - 8.032$	1%
4	7/12	$Y = 828.7\ X - 6.394$	1%
5	7/22	$Y = 854.1\ X - 6.647$	1%

Figure 28. Effect of field slope on sediment yield, 1976 bean tillage study.



Irrigation Number	Dates	Regression Equation	Level of Significance
1	5/21,5/24	Y = -2,880 X + 111	1%
2	6/21	Y = -5,780 X + 123	1%
3	6/30	Y = -2,580 X + 87	1%
4	7/12	Y = -2,064 X + 76	1%
5	7/22	Y = - 890 X + 68	1%

Figure 29. Effect of field slope on water retention, 1976 bean tillage study.

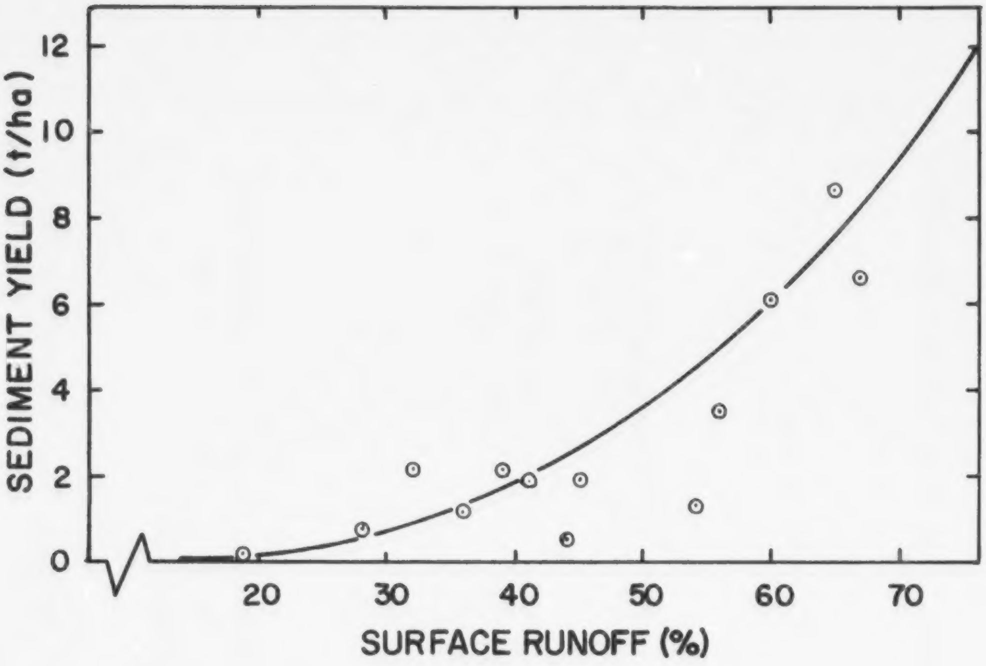


Figure 30. Relationship between sediment yield and surface runoff.

Water samples were analyzed for total suspended solids by filtering techniques outlined for the bean tillage study. Four 8-hour irrigations and one 24-hour irrigation were monitored. During the first irrigation, considerable difficulty was encountered with leakage under the sod and plastic and data from this irrigation are not reliable. Seven days prior to the fifth irrigation a hailstorm caused severe damage to the bean vines and furrows. A 24-hour set was required for this irrigation to adequately irrigate the lower end of the field.

Sediment loss data for the 12 mini-basins and check furrows are presented in Table 33 for four irrigations in 1976. The seasonal sediment loss from the field, as indicated by the average of the check furrow losses, would have been 14,950 kg/ha. The weighted average loss for the mini-basins was only 680 kg/ha. The average seasonal sediment removal efficiency of the basins was 94.9 percent.

Sediment removal efficiencies for the basins evaluated in this study are shown in Table 34. The data presented in this table indicate that there is no significant difference in the sediment removal efficiency of different sizes of mini-basins even though the average depth of the larger basins was less than that of the smaller basins. There is also no apparent benefit to using a grassed overflow section instead of a plastic section. It is doubtful that a farmer would spend the time and money required to install plastic sections. However, grassed overflow sections should be relatively easy to manage.

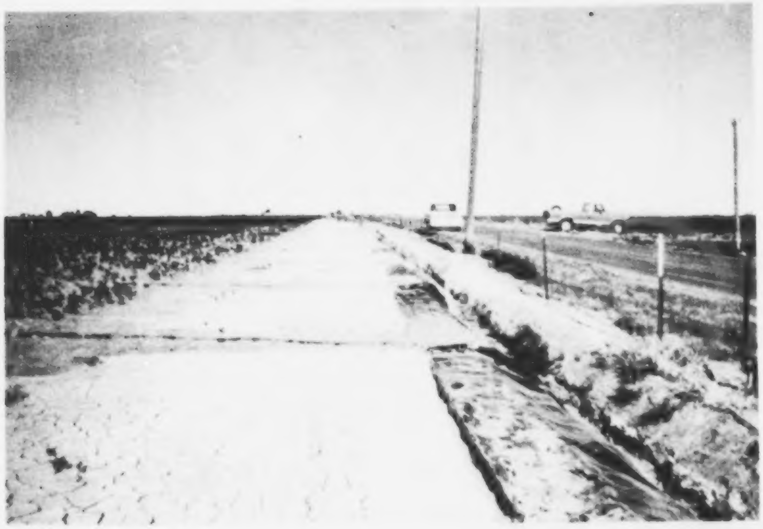


Figure 31. Mini-basins constructed on the lower end of a bean field.

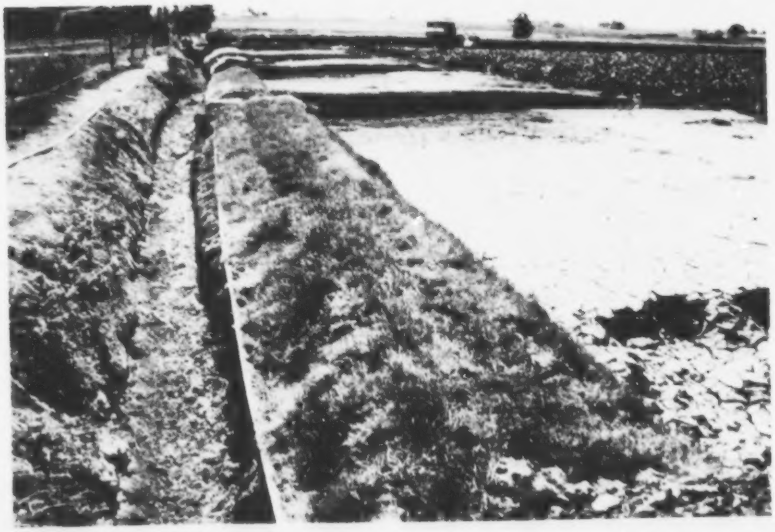


Figure 32. Mini-basins with grassed overflow sections.

TABLE 33. SEDIMENT LOSS DATA, 1976 MINI-BASIN STUDY

Irrigation Number	Sediment Loss (t/ha)[1]									
	2		3		4		5		Totals	
Basin Size[2] and Type	Basins	Check Furrows	Basins	Check Furrows	Basins	Check Furrows	Basins	Check Furrows	Basins	Check Furrows
3 g	0.23	3.24	0.36	3.36	0.21	3.94	0.13	3.94	0.93	13.48
3 p	0.16	4.03	0.11	4.31	0.20	5.71	0.21	2.49	0.69	16.54
4 g	0.12	4.07	0.10	3.60	0.15	6.43	0.04	0.58	0.50	14.67
4 p	0.19	3.30	0.22	2.59	0.18	3.43	0.13	1.76	0.72	11.08
5 g	0.22	4.40	0.18	3.31	0.20	5.32	0.04	4.70	0.63	17.72
5 p	0.20	3.58	0.15	2.41	0.21	5.26	0.21	4.90	0.77	16.18

[1] "t" is the abbreviation for metric ton (tonne)

[2] Symbols denote number of furrows (3, 4 or 5) collected by each basin and whether the overflow is grassed (g) or plastic lined (p)

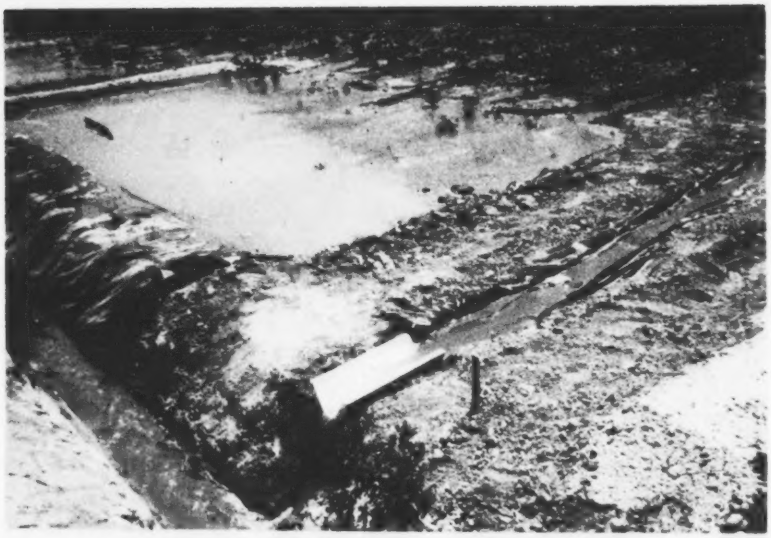


Figure 33. V-notch flume used to measure the flow in check furrows in the mini-basin study.

The construction and use of simple grassed overflow mini-basins would provide an economical means of retaining sediment on a field.

One of the 3-furrow basins was filled with sediment after five irrigations. This indicates that the larger 4- or 5-furrow basins are more likely to remain effective over a full season.

VEGETATED BUFFER STRIP STUDY

An evaluation of the effect of vegetative buffer strips on sediment losses from a spring wheat field was performed in 1976. A 1.8-hectare field at the Kimberly Center was divided into three plots, planted at a rate of 78 kg/ha with Twin variety spring wheat, harrowed and then corrugated with sled corrugators.

One month after the initial planting, a 2.44-meter wide grain drill was used to band the bottom of the field with multiple plantings of the spring wheat. Plot 1 was not banded, plot 2 was banded with a single planting and plot 3 was banded with a double planting. The plots were all the same size (approximately 0.6 hectares). The slopes of the three plots were 1.2, 1.4 and 1.7 percent, respectively.

Six irrigations were performed on each of the three plots using 6.5-hour sets. The water was applied with 19-mm diameter siphon tubes which were set with a constant differential head of 91 mm. Inlet flows were measured with a

TABLE 34. MINI-BASIN SEDIMENT REMOVAL EFFICIENCIES, 1976[1]

Basin Size[2] and Type	Irrigation Number 2	3	4	5	Seasonal Average
3 g	92.92	89.30	94.69	95.68	93.15
3 p	96.09	97.36	96.43	91.53	95.35
4 g	97.16	97.30	97.66	93.47	96.40
4 p	94.15	91.50	94.71	92.80	93.29
5 g	95.05	94.54	96.30	99.15	96.26
5 p	94.49	93.92	95.93	95.79	95.03

[1] The efficiencies are expressed as percentages

[2] Symbols denote number of furrows (3, 4 or 5) collected by each basin and whether the overflow is grassed (g) or plastic lined (p)

Cipolleti weir and a 90° V notch weir installed in the head ditch. The surface runoff from the field was measured with a 76-mm Parshall flume. All measuring stations were equipped with water stage recorders.

Sediment samples were taken at each water measurement station and from a random sampling of siphon tubes at the beginning, middle and near the end of each set. Runoff water in the Parshall flume was sampled at 15, 45, 105, 225 and 285 minutes after the beginning of flow in the flume and 15 minutes before and after the tubes were pulled at the end of each set.

Sediment samples were analyzed with the same procedure as outlined for the bean tillage study. Water and sediment flow onto and off the field were evaluated and plotted with the computer routine for each irrigation. A graph showing rates of sediment loss from the three plots during a typical irrigation is shown in Figure 34. Prior to harvest and after the sixth and last irrigation, stand density counts were made in the buffer strips on all three plots. Two subplots of 0.37 m^2 were sampled on each plot.

Flow and sediment yield data for the three plots are presented in Table 35. The average amount of water applied to the three plots during the season was 516 mm. The average runoff was 157 mm. The average net application was 359 mm. The estimated seasonal consumptive use by the crop was 230 mm.

The data in Table 35 show that, on a seasonal basis, the percent surface runoff values for the three plots were essentially the same. The seasonal sediment yields, on the other hand, varied markedly--from 1,828 kg/ha on the double-planted plot (plot 3) to 8,618 kg/ha on the check plot (Plot 1). The effect of the stand density of the wheat in the buffer strip on sediment yield is shown in Figure 35. Increasing the stand density from 519 to 815 stems/m^2 (an increase of 57 percent) resulted in over a fourfold decrease in the sediment yield.

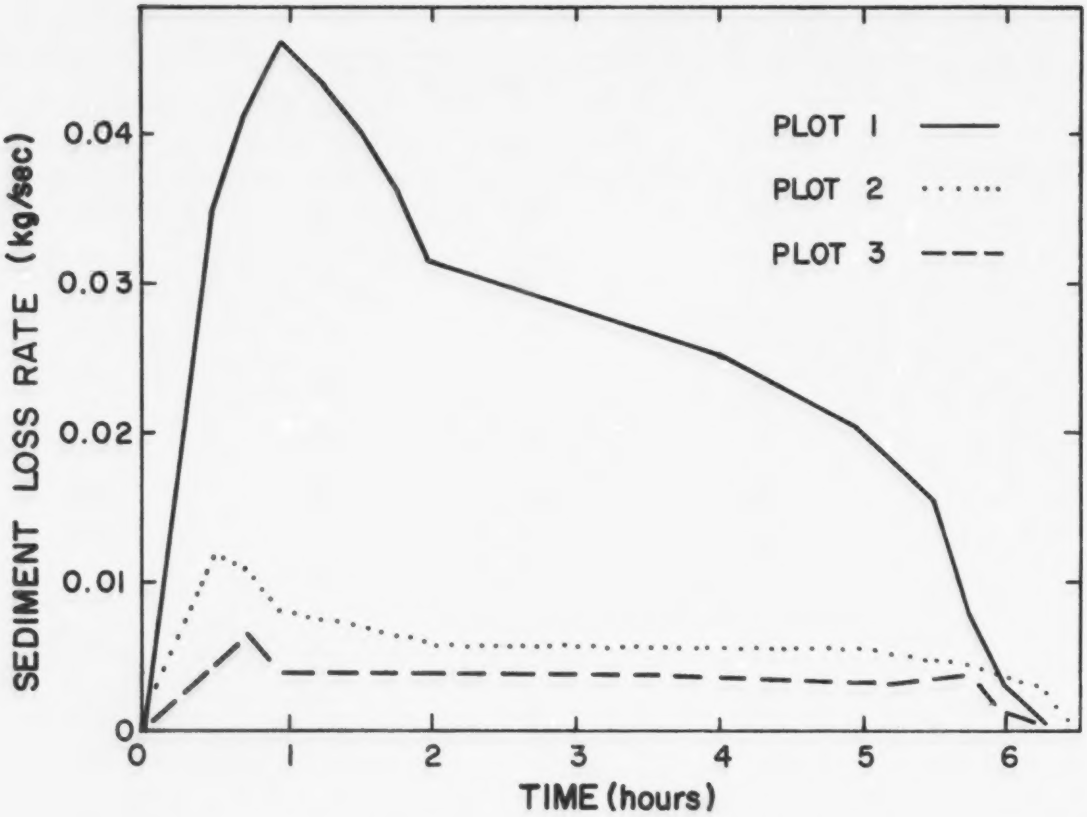


Figure 34. Sediment loss rates during a typical irrigation of the vegetated buffer strip study site in 1976.

Nonsignificant differences between plots in the total amounts of water applied and the amounts of surface runoff indicate that retardation of flow in the buffer strips was sufficient to remove sediment but did not increase infiltration appreciably. Planting the buffer strips required very little effort and did not disrupt normal irrigation or other farming operations.

SEDIMENT REMOVAL BY ALFALFA

A 1.52-hectare field of alfalfa at the Kimberly Center was monitored during 1975 to determine the magnitude of sediment reduction obtainable when surface runoff is reused for irrigation. The field was 146 meters long and had an average slope of 1.7 percent. The soil is Portneuf silt loam.

Four irrigations were monitored. The amounts of water and sediment coming onto and off the field were computed for each irrigation.

The results obtained from this monitoring program are presented in Table 36. The total amount of water applied during the season was 746 mm. Only

TABLE 35. FLOW AND SEDIMENT YIELD DATA, 1976 MAGIC VALLEY VEGETATED BUFFER STRIP STUDY

Irrigation	Inflow (mm)	Outflow (mm)	Surface Runoff (%)	Sediment Yield (kg/ha)
Plot 1, 519 stems/m^2				
1	108	24	22	2,926
2	92	21	23	1,625
3	84	28	33	1,119
4	78	29	37	1,073
5	87	30	34	946
6	86	30	35	929
Totals	535	162		8,618
Average			30	
Plot 2, 739 stems/m^2				
1	108	30	28	1,172
2	87	26	30	769
3	58	25	43	458
4	81	27	33	440
5	84	26	31	362
6	83	28	34	210
Totals	501	162		3,411
Average			32	
Plot 3, 815 stems/m^2				
1	101	29	29	600
2	76	23	30	352
3	84	22	26	256
4	94	24	26	274
5	83	24	29	217
6	76	26	34	129
Totals	514	148		1,828
Average			29	

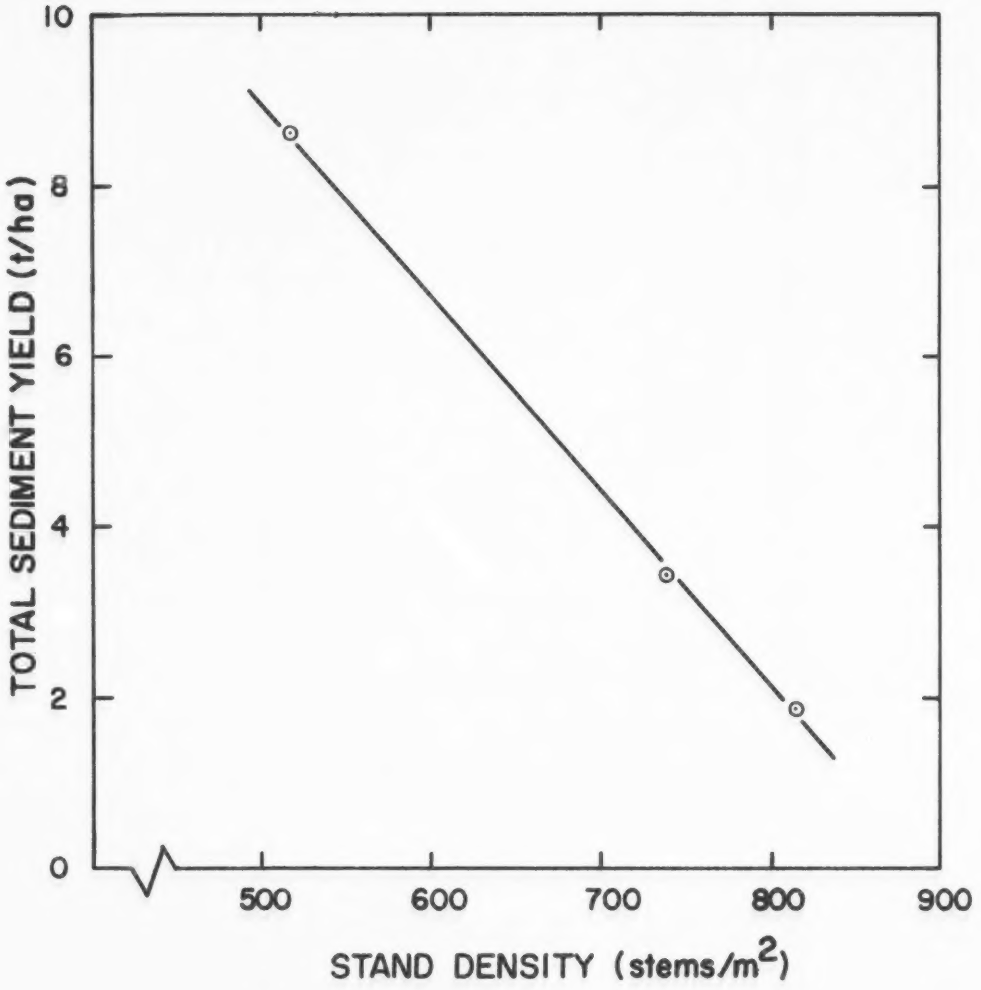


Figure 35. Effect of vegetated buffer strip stand density on sediment yield.

TABLE 36. FLOW AND SEDIMENT DATA, 1975 SEDIMENT REMOVAL BY ALFALFA STUDY

	Water			Sediment				
				Concentrations		Amounts		
Irrigation	Inflow (mm)	Outflow (mm)	Surface Runoff (%)	Inflow (mg/l)	Outflow (mg/l)	Inflow (kg/ha)	Outflow (kg/ha)	Amount Removed (%)
1	172	8	5	73	667	125	45	64
2	225	30	13	117	508	263	152	42
3	207	31	15	130	113	269	36	58
4	142	20	14	359	72	509	14	97
Totals	746	89				1,166	247	
Average			12	170	340			79

89 mm or 12 percent of the applied water left the field as surface runoff. The average sediment concentration of the outflow was 340 mg/l while that of the inflow was 170 mg/l. The net sediment removal varied from 42 percent for the first irrigation to 97 percent for the fourth irrigation, and averaged 79 percent for the season. These results show that utilization of sediment laden runoff to irrigate a dense growing crop such as alfalfa is a viable method for improving water quality and retaining sediment on farm fields.

FURROW CUTBACK IRRIGATION STUDY

The effects of furrow cutback irrigation on water and sediment losses from a potato field were evaluated in 1975. This study was conducted on a 1.69-hectare field at the Kimberly Center which was 146 meters long and had a slope of 1.0 percent. The field was divided into two equal plots. Each plot was irrigated 12 times during the season using 19-mm siphon tubes. On alternate irrigations, the irrigator was asked to cut the siphon tube flow back after the water had reached the ends of the furrows. Each plot received 12 uncontrolled or non-cutback irrigations and 12 controlled or cutback irrigations.

The flow onto the field was determined for each set by measuring the difference in discharge between two weirs in the head ditch or by calibrating the siphon tubes to determine their average flow rates. The runoff from the potato field was measured through a 76-mm Parshall flume equipped with a continuous recorder. The runoff then entered a sediment pond which was monitored for sediment removal efficiency. The water sampling and analysis procedures were the same as those used in the bean tillage study.

Water and sediment budgets for the potato field for both the cutback and non-cutback sets are given in Tables 37 and 38. On the non-cutback sets, 853 mm or about 57 percent of the applied water (1,487 mm) left the sets as surface runoff during the season. This resulted in a net application of 634 mm of water to these sets. On the cutback sets, however, only 241 mm or about 20 percent of the applied water (1189 mm) left the sets as surface runoff. The net application in this case was 948 mm. The estimated seasonal consumptive use by the crop was 546 mm. This means that the estimated water-use efficiencies for the non-cutback and cutback irrigations were 37 and 46 percent, respectively.

The data in Tables 37 and 38 show that sediment losses are directly related to surface runoff. The non-cutback irrigations, for example, resulted in 853 mm of surface runoff and a net sediment loss of 92,540 kg/ha. The cutback irrigations, on the other hand, resulted in only 241 mm of runoff and a net sediment loss of 12,295 kg/ha. In this case, a 72 percent reduction in surface runoff resulted in an 87 percent decrease in the net amount of sediment lost. The utilization of cutback systems on the loessal soils in the Magic Valley area would be useful in decreasing water use as well as decreasing sediment losses. Additional labor would be required, however, to cut furrow flows back as was done in this study.

TABLE 37. FLOW DATA, 1975 FURROW CUTBACK STUDY

Irrigation Number	Length of Set (hrs)	Inflow		Outflow		Surface Runoff	
		Cutback (mm)	Non-Cutback (mm)	Cutback (mm)	Non-Cutback (mm)	Cutback (%)	Non-Cutback (%)
1	10.00		126.7		40.6		32.1
	9.50	97.8		15.8		16.2	
2	7.75	78.6		9.9		12.6	
	7.67		95.6		51.4		53.7
3	6.50		79.8		54.0		67.7
	7.00	72.1		7.2		10.0	
4	7.58	80.1		12.7		15.9	
	7.42		95.0		46.4		48.8
5	7.50		92.1		48.6		52.7
	7.50	77.7		18.2		23.4	
6	20.67	212.9		38.0		17.8	
	24.00		294.8		208.6		71.8
7	11.67		147.3		85.7		58.2
	12.00	120.2		42.5		35.4	
8	12.00	123.5		25.1		21.3	
	13.00		159.7		107.1		67.1
9	11.58		147.3		81.8		55.5
	12.00	119.3		18.3		15.3	
10	7.25	73.3		13.4		19.3	
	7.00		89.0		36.7		41.2
11	7.00		85.9		51.7		60.2
	7.00	72.1		24.6		34.1	
12	6.00	61.8		15.5		25.1	
	6.00		73.7		40.9		55.8
Totals		1,189.4	1,486.9	241.2	853.4		
Averages						20.3	57.4

TABLE 38. SEDIMENT DATA, 1975 FURROW CUTBACK STUDY

Irrigation Number	Length of Set (hrs)	Inflow		Outflow	
		Cutback (kg/ha)	Non-Cutback (kg/ha)	Cutback (kg/ha)	Non-Cutback (kg/ha)
1	10.00		194.3		4,307.0
	9.50	78.3		1,238.0	
2	7.75	93.5		598.3	
	7.67		62.9		7,151.3
3	6.50		178.7		6,577.7
	7.00	67.6		403.1	
4	7.58	384.0		2,505.7	
	7.42		94.3		9,126.6
5	7.50		180.5		12,392.0
	7.50	83.5		2,594.4	
6	20.67	451.8		3,301.5	
	24.00		463.0		37,068.9
7	11.67		217.0		8,912.0
	12.00	54.4		2,479.4	
8	12.00	154.5		685.5	
	13.00		206.0		4,324.4
9	11.58		127.3		2,841.0
	12.00	67.5		161.1	
10	7.25	30.5		129.4	
	7.00		44.6		443.0
11	7.00		110.6		1,366.5
	7.00	278.4		135.6	
12	6.00	270.0		76.5	
	6.00		321.9		240.0
Totals		2,014.0	2,201.1	14,308.5	94,740.9

DISTRICT WASTE WATER PONDS

The K Lateral wasteway pond near the Jerome golf course has been monitored since 1972. This pond is 152 meters long, 18.3 meters wide and 1.5 meters deep. The Northside Canal Company constructed inlet and outlet structures and a by-pass channel at this site in 1972. The inlet structure and by-pass channel are shown in Figure 36. The outlet structure, which consists of a weir equipped with a stage recorder, is shown in Figure 37. The pond was surveyed in 1972, 1973 and 1974 to determine the volume of material removed by cleaning with a dragline for comparison with the calculated volume of sediment deposited in the pond. The pond was cleaned again in 1976.

This pond collects return flow from 2,428 hectares of Northside Canal Company land near Jerome, Idaho. The soils in the area are primarily silt to sandy silt. The pond discharge is measured with a 2.4-meter rectangular suppressed weir which is equipped with a stage recorder. Water samples were taken every two weeks throughout each irrigation season by Agricultural Research Service personnel and analyzed for total suspended solids and phosphorus.

Two additional large ponds were constructed by the Northside Canal Company on the J-8 Lateral in 1975. These ponds are 91.5 meters long and were constructed parallel to each other. One is 21.3 meters wide while the other one is 39.6 meters wide. Water measurement devices and controls and concrete overflow sections were installed. Due to low runoff flows in 1976 and difficulties with calibration of the inlet flumes, no meaningful data were obtained from this installation.

Seasonal flow and sediment removal data for the K Lateral pond are given in Table 39. As can be seen, the seasonal sediment removal efficiency of this pond varied from 65 to 78 percent in the period from 1972 through 1976. Total phosphorus measurements indicate that the phosphorus removal efficiencies of this pond were from 6 to 10 percent less than the sediment removal efficiencies during the 5-year monitoring period.

Flow data for the K Lateral pond have been analyzed to determine the characteristics of the flow into this pond. A frequency analysis of discharge measurements at 6-hour intervals over the 1975 season indicated an average discharge of 0.4 m^3/sec with a variation of from 0 to 1.1 m^3/sec. Ninety-two percent of the total seasonal runoff from the K Lateral watershed occurs at flows which are less than 50 percent of the maximum discharge. Data of this type have been collected and analyzed for 15 runoff streams in southern Idaho to develop criteria for designing sediment ponds (Bondurant et al., 1976).

The data in Table 39 show that large sediment removal ponds are effective in significantly improving the quality of return flows from large irrigated areas. Operational sediment removal efficiencies of ponds vary because of discharge fluctuations and variations in particle size and sediment concentration. Several factors affect the short-term sediment concentration in runoff streams. Abrupt changes in crop type can significantly affect the sediment load. For instance, a large conversion from pasture and alfalfa to row crops due to abrupt commodity price changes would probably result in increased sediment loads.

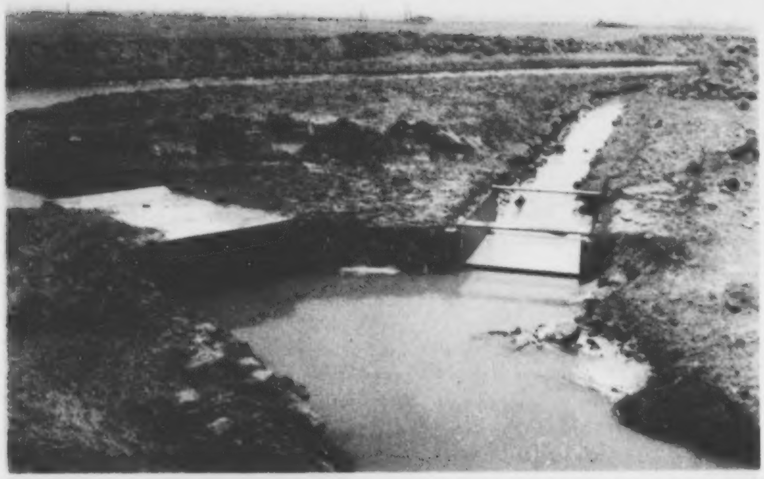


Figure 36. Inlet structure and by-pass channel of the K Lateral wasteway pond near Jerome, Idaho.

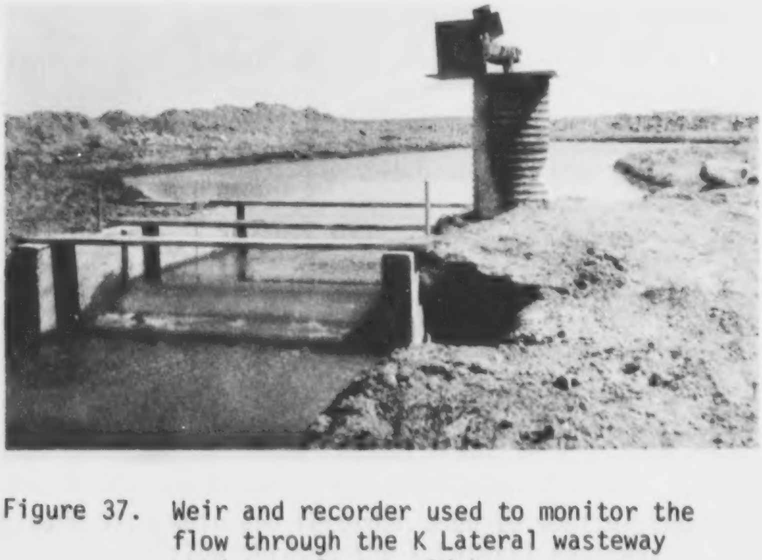


Figure 37. Weir and recorder used to monitor the flow through the K Lateral wasteway pond near Jerome, Idaho.

TABLE 39. SEASONAL FLOW AND SEDIMENT REMOVAL DATA FOR THE K LATERAL POND NEAR JEROME, IDAHO

	1972	1973	1974	1975	1976
Total Flow (1000 m^3)	4,990	5,280	6,330	3,022	7,900
Sediment Removal Range (%)	36-77	20-76	0-90	43-85	31-79
Average Sediment Removal (%)	65	67	74	78	68
Total Sediment Retention (t)	456	510	735	790	1,284

SUMMARY

The results of the field investigations conducted in the Magic Valley during the 1975 and 1976 irrigation seasons show that sediment and phosphorus losses from surface-irrigated lands are affected by a number of factors and that these losses can be effectively controlled. The results of a tillage study on beans show, for example, that preplant irrigation practices affect these losses. A "banded" preplant irrigation where 122-cm furrow spacings were used to wet only the seedbed area resulted in a 76 percent decrease in the sediment loss in comparison to a "broadcast" preplant irrigation where 76-cm furrow spacings were used to wet the entire field surface. No significant differences in sediment and total phosphorus losses due to cultivation practices were found in this study. The total sediment loss from the bean field during five irrigations in 1976 was 8,164 kg/ha with a corresponding total phosphorus loss of 7.38 kg/ha. Surface runoff was found to be the best single indicator of sediment losses from this field, with losses increasing as the runoff (expressed as a percentage of applied irrigation water) increased.

Mini-basins which collect and detain the runoff from several adjacent furrows prior to discharging the runoff water over a drain ditch berm can remove up to 95 percent of the total sediment from the runoff from a field. Evaluations of twelve mini-basins constructed on the lower end of a bean field showed that the basins reduced the seasonal sediment loss from the field from 14,950 kg/ha to 680 kg/ha. Basins with grassed overflow sections which collect the runoff from 4 or 5 furrows are recommended.

Vegetated buffer strips consisting of multiple plantings of wheat across the lower end of a spring wheat field were found to be effective in reducing sediment losses from this field. Two extra plantings of a 2.44-meter wide strip of grain resulted in a 79 percent reduction in the amount of sediment lost during the season (from 8,619 kg/ha on the single-planted check plot to 1,828 kg/ha on the triple-planted plot). Stand density counts showed that there is an inverse linear relationship between stand density in the buffer strips and sediment yield. Increasing the stand density from 519 to 815 stems/m^3 (an increase of 57 percent) resulted in over four-fold decrease in sediment loss. Planting the buffer strip required little extra effort and presented no inconvenience in normal farming operations. The use of buffer strips on other crops will require integration of the use of the strips with other farming practices.

The effectiveness of mature alfalfa stands in removing sediment from surface runoff which is reused for irrigation was documented in 1975. Monitoring of the amounts of water and sediment entering and leaving an alfalfa field showed that 12 percent of the applied water left the field and that 79 percent of the sediment in the applied water was removed, even though sediment concentrations in the runoff were double those in the inflow. Using the sediment-laden runoff from row crops to irrigate alfalfa or other close growing crops is a viable method for improving the quality of return flows from surface-irrigated areas.

Furrow cutback irrigation was shown to be effective in reducing water and sediment losses from a field planted to potatoes. Non-cutback irrigations of this field resulted in 853 mm of surface runoff during the irrigation season (12 irrigations) and a net sediment loss of 92,540 kg/ha. The cutback irrigations resulted in only 241 mm of runoff and a net sediment loss of 12,295 kg/ha. These results emphasize the importance of water-use practices in controlling sediment losses. In this case, a 72 percent reduction in the amount of surface runoff resulted in an 87 percent decrease in the amount of sediment lost.

The use of large ponds to remove sediment from the runoff in wasteways is an alternative to the use of on-farm retention systems or control practices. The results of five years of monitoring a large pond which collects the runoff from a 2,340-hectare watershed show that the average sediment and phosphorus removal efficiencies of this pond were about 70 and 62 percent, respectively. In 1976, 1,284 metric tons of sediment were retained in this pond. This is equivalent to a loss of approximately 530 kg/ha from the entire watershed. Data obtained for this and similar ponds are being used to develop criteria for designing both small on-farm sediment ponds and larger district-type ponds.

SECTION 8

ECONOMICS OF CONTROL PRACTICES

In this section of the report, cost effectiveness estimates for selected methods of reducing sediment losses from irrigated farms are described. Farm income consequences of having to meet specified restrictions on sediment losses are also discussed. The calculations are based on data from the previously described field investigations and from a survey of farms in the Boise and Magic Valley areas.

The balance of this section is organized into three subsections. First, the farm survey procedure and results are summarized. Then, estimates of costs associated with selected methods of sediment loss reduction are described. The effects of sediment loss restrictions on farm income are discussed in the third subsection.

FARM SURVEY

The farm survey was conducted after the harvest season in 1975. One-hundred and fifty randomly selected farm operators were interviewed and asked to describe their present farming practices, with special emphasis on field operations and irrigation practices. The study areas were delineated so that the farms within them had soils, topography, and water supply conditions similar to those at the sites where the field investigations were conducted. The study area in Twin Falls County consisted of the irrigated land with predominantly Portneuf silt loam soil that lies between the Snake River and the irrigation canal east of the city of Twin Falls. Field slopes are four percent or less. All irrigation water is supplied by the Twin Falls Canal Company, which diverts the water out of the Snake River at Milner Dam.

From the 62 sections of land (1 section = 640 acres or 259 hectares) in the study area, twelve were selected at random. After the sample sections were located on a map, the farm interviews were carried out. The goal was to interview everyone who farmed 16 hectares or more of irrigated land in the sample sections. Forty-two farmers were contacted and 40 interviews were conducted.

The study area in Jerome County consisted of 70 sections of irrigated land lying east and south of Jerome. Most of the soils in this area are silt loams. Irrigation water is supplied by the Northside Canal Company. Data collection proceeded just as it did in Twin Falls County. Fourteen sections were selected at random from the 70 in the study area. Forty-five farmers were contacted and 40 interviews were conducted.

Two study areas were delineated in Canyon County on the basis of the soil associations mapped in the soil survey for the county. The Wilder-Parma area included three tracts of the Greenleaf-Nyssaton-Garbutt Association. The Nampa-Melba area included areas of the Power-Purdam Association together with the Minidoka-Marsing-Vickery Association. This is the combination of soils found on the Caldwell Research and Extension Center. In the southern part of this area, the Scism-Bahem-Trevino Association predominates. Fifteen percent of the sections in each of these areas were selected at random. Interviews were conducted with farm operators according to the procedure used in the Magic Valley. Twenty-three interviews were conducted in the Wilder-Parma area. Forty-seven were made in the Nampa-Melba area.

Analysis of Survey Data

The information from the farm survey was analyzed so that representative farm models could be constructed for each of the four study areas.

The sample farms in each study area were classified into two size categories. Then crop rotations and resource combinations (especially machinery and labor) were studied for the farms in each category to arrive at a typical or bench mark farm model to represent each size category in each study area. Typical tillage, cultural, and irrigation practices associated with each crop were identified from the survey data. This information was combined with input and commodity prices. The Oklahoma State University budget generator was then used to produce cost-and-return budgets for each crop included in the farm models.

Farm Models - Magic Valley

Of the 40 interviews conducted in the Twin Falls area, only 36 of these were considered to be representative of this study area. The other four were with farmers who worked land that lay mostly outside the study area. Based on 1975 irrigated crop area data, the 36 sample farms were classified into two size categories as shown in Table 40. The choice of the breakpoint between the two categories was based mainly on labor requirements. Typically, only one man is employed on farms of less than 100 hectares. Two or more men are usually employed on larger farms.

TABLE 40. SIZE CLASSIFICATION OF SAMPLE FARMS IN TWIN FALLS COUNTY

Size Category (irrigated hectares)	Number of Farms	Median Farm Size (irrigated hectares)
Up to 100	21	56.7
More than 100	15	129.7

The principal crops on the sample farms were garden bean seed, alfalfa hay, commercial beans, garden pea seed and small grains (predominantly wheat). Irrigated cropland use in the Twin Falls area is summarized in Table 41.

TABLE 41. IRRIGATED CROPLAND USE ON SAMPLE FARMS IN THE TWIN FALLS STUDY AREA

Crops	Percent of Irrigated Cropland Small Farms	Large Farms	All Farms
Garden Bean Seed	42	24	29
Alfalfa Hay	23	22	23
Commercial Beans	14	15	14
Small Grain	10	12	11
Garden Pea Seed	10	10	10
Sugarbeets	1	6	5
All Corn	1	9	6
All Other	0	2	2
	100	100	100

A representative farm was described for each size category. The size of the representative farm is equal to the median farm size in the corresponding category. The crop rotations on the two model farms for the Twin Falls area are shown in Table 42.

TABLE 42. CROPS GROWN ON MODEL FARMS FOR THE TWIN FALLS STUDY AREA

	Crop	Area (ha)
Small Farm Model		
	Garden Bean Seed	24.3
	Commercial Beans	8.1
	Garden Pea Seed	8.1
	Alfalfa (2-year stand)	16.2
		56.7
Large Farm Model		
	Garden Bean Seed	32.4
	Commercial Beans	24.3
	Spring Wheat	24.3
	Garden Pea Seed	16.2
	Alfalfa (2-year stand)	32.4
		129.6

Forty interviews were conducted in the Jerome study area. It was found that soils in the western part of this area were sandier than those to the east and south of the town of Jerome. Since the sandy soils were not very similar to those on which the field investigations were conducted, it was decided to construct farm models on the basis of the 29 sample farms with heavier soils. The sample farms for this area were classified into two size categories in the same way as described for the Twin Falls study area. The classifications for the Jerome area are given in Table 43.

TABLE 43. SIZE CLASSIFICATION OF SAMPLE FARMS IN JEROME COUNTY

Size Category (irrigated hectares)	Number of Farms	Median Farm Size (irrigated hectares)
Up to 100	18	56.7
More than 100	11	121.5

The principal crops on the smaller sample farms were alfalfa hay, small grains and commercial beans. The same crops predominated on the larger farms where potatoes was also a major crop. Table 44 summarizes irrigated cropland use for the sample farms in the Jerome area. Representative farms were described for the two size categories according to the procedure used for the Twin Falls study. The crop rotations on the two model farms are shown in Table 45.

TABLE 44. IRRIGATED CROPLAND USE ON SAMPLE FARMS IN THE JEROME STUDY AREA

	Percent of Irrigated Cropland		
Crop	Small Farms	Large Farms	All Farms
Alfalfa Hay	44	27	33
Small Grain	25	23	24
Dry Beans	23	13	16
Potatoes	2	20	13
All Corn	4	10	8
Sugarbeets	0	4	3
All Other	2	3	3
	100	100	100

TABLE 45. CROPS GROWN ON MODEL FARMS FOR THE JEROME STUDY AREA

	Crop	Area (ha)
Small Farm Model		
	Commercial Beans	16.2
	Spring Wheat	16.2
	Alfalfa (5-year stand)	24.3
		56.7
Large Farm Model		
	Potatoes	32.4
	Commercial Beans	24.3
	Spring Wheat	32.4
	Alfalfa (4-year stand)	32.4
		121.5

Farm Models - Boise Valley

The 23 sample farms in the Wilder-Parma study area were classified into two size categories, as shown in Table 46.

TABLE 46. SIZE CLASSIFICATION OF SAMPLE FARMS IN THE WILDER-PARMA STUDY AREA

Size Category (irrigated hectares)	Number of Farms	Median Farm Size (irrigated hectares)
Up to 100	15	56.7
More than 100	8	137.7

The principal crops on the sample farms were sugarbeets, alfalfa hay, potatoes, wheat and barley. Irrigated cropland use in the Wilder-Parma area is summarized in Table 47. Crop rotations for the two representative farm models for this area are shown in Table 48.

The 47 sample farms in the Nampa-Melba study area were classified into two size categories as shown in Table 49. The principal crops on the sample farms were sugarbeets, corn seed, dry beans and wheat. Alfalfa was an important crop on the smaller farms. Irrigated cropland use in this area is summarized in Table 50. Crop rotations for the two representative farm models are shown in Table 51.

TABLE 47. IRRIGATED CROPLAND USE ON SAMPLE FARMS IN THE WILDER-PARMA STUDY AREA

Crop	Percent of Irrigated Cropland Small Farms	 Large Farms	 All Farms
Sugarbeets	30	28	29
Alfalfa Hay	15	16	15
Potatoes	14	14	14
Wheat	13	10	11
Barley	10	11	11
Onions	1	7	5
Corn Silage	5	3	4
Alfalfa Seed	0	6	4
Dry Beans	6	0	2
All Other	6	5	5
	100	100	100

TABLE 48. CROPS GROWN ON MODEL FARMS FOR THE WILDER-PARMA STUDY AREA

	Crop	Area (ha)
Small Farm Model		
	Sugarbeets	16.2
	Potatoes	16.2
	Winter Wheat	16.2
	Alfalfa Hay (3-year stand)	8.1
		56.7
Large Farm Model		
	Sugarbeets	40.5
	Potatoes	32.4
	Winter Wheat	32.4
	Alfalfa Hay (3-year stand)	32.4
		137.7

TABLE 49. SIZE CLASSIFICATION OF SAMPLE FARMS IN THE NAMPA-MELBA STUDY AREA

Size Category (irrigated hectares)	Number of Farms	Median Farm Size (irrigated hectares)
Up to 100	29	64.8
More than 100	18	129.6

TABLE 50. IRRIGATED CROPLAND USE ON SAMPLE FARMS IN THE NAMPA-MELBA STUDY AREA

	Percent of Irrigated Cropland		
Crop	Small Farms	Large Farms	All Farms
Sugarbeets	23	31	28
Corn Seed	14	11	12
Dry Beans	15	8	11
Wheat	11	10	10
Barley	3	10	8
Alfalfa Hay	12	3	6
Potatoes	1	8	6
Alfalfa Seed	2	5	4
Vegetables	3	9	7
Vegetable Seed	7	3	5
All Other	9	2	3
	100	100	100

TABLE 51. CROPS GROWN ON MODEL FARMS FOR THE NAMPA-MELBA STUDY AREA

	Crop	Area (ha)
Small Farm Model		
	Sugarbeets	24.3
	Corn Seed	16.2
	Dry Beans	16.2
	Alfalfa Hay (3-year stand)	8.1
		64.8
Large Farm Model		
	Sugarbeets	56.7
	Corn Seed	24.3
	Dry Beans	24.3
	Winter Wheat	24.3
		129.6

COST EFFECTIVENESS OF SELECTED SEDIMENT CONTROL PRACTICES

The surface irrigation method under consideration in this section involves the use of furrows or corrugates to distribute water over a field. However, even with just one method of water application, the sediment loss from a surface-irrigated field is a function of many parameters. Included in these parameters are soil characteristics, field topography and the rate and time of water application.

Irrigation water supply, return flow and sediment loss were estimated for typical crop and field conditions in the study areas. The estimates of annual sediment loss are presented in Table 52. These estimates assume silt loam soils with slopes varying from one-half to four percent, and are based on data obtained from field investigations conducted in the study areas over the past five years (Ballard, 1975; Fitzsimmons et al., 1977 and Watts et al., 1974).

The physical effectiveness of the sediment reduction practices considered in this chapter was estimated on the basis of field experiments conducted by Fitzsimmons et al. (1977). These estimates are presented in Table 53 and are expressed in terms of the percentage reduction in the sediment loss that could be achieved by using a particular practice. The sediment loss reduction practices are described in the following paragraphs.

TABLE 52. SEDIMENT LOSS FROM SURFACE-IRRIGATED CROPS UNDER TYPICAL FARM CONDITIONS IN THE BOISE AND MAGIC VALLEY AREAS

Crops	Annual Sediment Loss (kg/ha)
Potatoes	40,340
Corn, Beans and Sugarbeets	8,070
Small Grain and Peas	3,140
Alfalfa	900

TABLE 53. ESTIMATED SEDIMENT LOSS REDUCTION FOR SELECTED CONTROL PRACTICES

Control Practice	Sediment Loss Reduction (%)
Flow Cutback	30
Vegetative Buffer Strip	50
Sediment Pond	67
Mini-Basins	90
Sprinklers	100

Sediment Loss Reduction Practices

Flow cutback involves running the usual amount of water down a furrow or corrugate until the water is through to the lower end, then cutting the stream size back for the remainder of the irrigation set. This reduced flow results in less erosion and less soil transport in the furrows. However, more labor is required to perform the cutback operation. In this study, it was assumed that the irrigation labor requirement would be doubled because, in essence, the water must be set and then reset. Based on the estimates in Table 53, flow cutback would reduce the sediment loss from a field by 30 percent. On a typical bean field, the total loss would be reduced from 8,070 kg/ha to 5,650 kg/ha.

Vegetative buffer strips are strips of close growing crops such as grass or grain which are established across the lower end of a field to slow the velocity of the water running off the field, causing it to deposit some of its sediment. Crops that are normally planted with a drill can be double or even triple-planted in a buffer strip across the lower end of a field.

A sediment pond is a pond dug into a waterway for the purpose of reducing flow velocity and retaining sediment. The effectiveness of such a pond depends on its shape and size and on the volume of flow going through it. The results presented previously (Table 28) show that on-farm ponds retain about two-thirds of the sediment coming into them.

Mini-basins are small shallow ponds constructed at the lower end of a field by putting in a low berm or dike along the bank of the drain ditch. Other berms are constructed perpendicular to the drain ditch so that each basin retains the runoff from a small number of furrows. Since the berm along the drain ditch also serves as a spillway when necessary, it should be seeded with grass to minimize erosion of the berm.

Sprinklers are in use in many western areas, mainly in areas that do not have facilities for surface irrigation or that have soils that are difficult to surface irrigate. Some land is being converted to sprinkler irrigation using power-move systems, largely for the sake of labor saving and field consolidation. It is usually possible to design and operate sprinkler systems so that the water application rate is less than the soil intake rate. When this is done, surface runoff and resulting sediment losses are eliminated.

Economic Analysis

The assumptions and calculations involved in determining the cost effectiveness of selected sediment loss control practices are described in the following paragraphs.

Flow Cutback - The irrigation labor that is typically involved in growing a crop was computed on the basis of the farm survey data. For each crop, the median number of irrigations was multiplied by 1.0 hour/hectare/irrigation to compute the hours of irrigation labor used per hectare over the irrigation season. This time does not include pre-season ditch work on the farm which was computed separately for the crop budget.

It was assumed that the cutback procedure would double irrigation labor time, which was valued at $3.00 per hour. Costs associated with the use of the flow cutback method are presented in Table 54. For purposes of comparison, the cost per metric ton ($/t) of sediment retained on the field is computed on the basis of both a 30 percent and an 80 percent retention of the sediment that would be lost under typical present management conditions. The results of the previously discussed field investigations show a large variability in percentage retention achieved by cutting furrow flows back -- from 16 to nearly 100 percent.

Vegetated Buffer Strips - For row crops,the use of a grass or grain buffer strip at the end of a field would probably entail taking some land out of production. In order to estimate the area of land involved, it was necessary to make some assumptions regarding field size and shape. From the farm survey data, and from air photos in the Canyon Area Soil Survey, it was noted that the majority of fields in the study area were either 4.05- or 8.1-ha tracts. The 8.1-ha fields were usually rectangular, with dimensions of 201 by 402 meters. Water may run across either the short or the long side of the field

TABLE 54. COSTS ASSOCIATED WITH USING FLOW CUTBACK TO REDUCE SEDIMENT LOSS ON A TYPICAL FARM IN THE BOISE OR MAGIC VALLEY AREAS

Crop	Number of Irrigations	Irrigation Labor		Added Labor Cost ($/ha)	Sediment Retained		Cost of Sediment Retained	
		Normal (hr/ha)	Cutback (hr/ha)		30% Retention (t/ha)[1]	80% Retention (t/ha)	30% Retention ($/t)	80% Retention ($/t)
Dry Beans	7	7	14	21.00	2.42	6.45	8.68	3.26
Bean Seed	8	8	16	24.00	2.42	6.45	9.92	3.72
Corn	7	7	14	21.00	2.42	6.45	8.68	3.26
Sugarbeets	10	10	20	30.00	2.42	6.45	12.40	4.65
Potatoes	12	12	24	36.00	12.10	32.27	2.98	1.12
Pea Seed	5	5	10	15.00	0.94	2.51	15.96	5.98
Winter Wheat	5	5	10	15.00	0.94	2.51	15.96	5.98
Spring Wheat	4	4	8	12.00	0.94	2.51	12.77	4.78
Alfalfa Hay	6	6	12	18.00	0.27	0.72	66.67	25.00

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[1] "t" is the abbreviation for tonne or metric ton (1000 kg)

depending on the field slope. For the sake of standardization, it was assumed that all field are 8.1 hectares in size and that the lower ends of the fields are 300 meters in length. If the seeded strip is 2.44 m wide, then 732 m^2 or 0.0732 hectares of land would be taken out of production.

It was further assumed that, for row crops, the lower ends of fields are less productive per unit area than the rest of the field; that is, the land taken out of production would have yielded 80 percent of the field average used in the crop budgets. For grain and peas, it was assumed that a normal harvest would be taken from the overplanted strip. No overplant procedure was used with alfalfa.

The costs of taking row crop land out of production for vegetative strips, based on opportunity cost or the value of production given up, are presented in Table 55. Calculations have not been included for potatoes since a vegetative strip would probably be obliterated by the first irrigation of the potatoes.

TABLE 55. OPPORTUNITY COST OF LAND TAKEN OUT OF PRODUCTION FOR VEGETATIVE STRIPS (AVERAGE FOR FARM MODELS)

	Net Return to Land and Management		
Crop	Field Average ($/ha)	Strip Area (20% Lower Yield) ($/ha)	Opportunity Cost for Taking 0.0732 ha of Land Out of Production ($)
Dry Beans	529	334	24.45
Bean Seed	988	688	50.36
Corn Seed	806	477	34.92
Sugarbeets	875	504	36.90

The operating costs include the costs associated with planting the strip and spreading deposited sediment back on the field after harvest. For row crops, the time involved in getting the drill set up to plant a strip, driving to the field, planting the strip, driving back to the farmstead and putting the drill away is difficult to estimate. In calculating labor and machinery variable costs, the actual field time was multiplied by four in an attempt to include all the steps in the operation. For grain and pea fields, only the time involved in making another pass over the lower end of the field was used in computing costs.

Machine field time and variable costs per hour of operation came from the model farm budgets for grain enterprises. It was assumed that the farmer already had the machinery and that machinery fixed costs had already been allocated to crop enterprises. Therefore, no fixed costs were charged to the strips. Table 56 shows the calculation of operating costs for row crops, grain and peas. Total annual costs for vegetative strips are shown in Table 57.

TABLE 56. ANNUAL OPERATING COSTS ASSOCIATED WITH USING VEGETATIVE STRIPS ON 8.1-HECTARE FIELDS

Row Crops		
Machine variable costs for drill and tractor: $3.88/hr x 0.86 hr/ha x 0.0732 ha x 4	= $ 0.98	
Labor cost of seeding: $3.00/hr x 0.86 hr/ha x 0.0732 ha x 4	= 0.76	
Wheat or barley seed: 100 kg/ha x 0.0732 ha x $0.24/kg	= 1.76	
Sediment spreading: $3.70/ha x 8.1 ha	= 29.97	
	$33.47	
Corrugated Crops	Grain	Peas
Machine variable costs for drill and tractor: $3.88/hr x 0.86 hr/ha x 0.0732 ha	= $ 0.24	$ 0.24
Labor cost of seeding: $3.00/hr x 0.86 hr/ha x 0.0732 ha	= 0.19	0.19
Seed wheat	= 1.76	
Seed peas	=	6.40
Sediment spreading: $3.70/ha x 8.1 ha x .05	= 14.98	14.98
Total annual operating costs	$17.17	$21.81

Sediment spreading could be accomplished by making an extra pass over the field with a land plane. This would probably have to be done every year for row crops and every other year for grain and peas. Based on figures from the cost budgets, this operation would cost $3.70 per hectare.

Sediment Ponds - In determining the cost effectiveness of sediment ponds, it was assumed that a pond would be used for each 8.1-ha field. Pond size and excavation costs depend on the volume of sediment to be handled. The figures used in this study are shown in Table 58. Since sediment spreading costs are usually about equivalent to excavation costs, excavation costs were doubled to arrive at the annual operating costs for sediment ponds (Table 59).

TABLE 57. TOTAL ANNUAL COSTS ASSOCIATED WITH USING VEGETATIVE STRIPS ON 8.1-HECTARE FIELDS

Crop	Opportunity Cost of Land Taken Out of Production ($)	Operating Costs ($)	Total Costs Whole Field ($)	Total Costs Per Hectare ($)	Sediment Retained (t/ha)	Cost of Sediment Retained ($/t)
Dry Beans	24.45	33.47	57.92	7.15	4.03	1.77
Bean Seed	50.36	33.47	83.83	10.35	4.03	2.57
Corn Seed	34.92	33.47	68.39	8.44	4.03	2.10
Sugarbeets	36.90	33.47	70.37	8.69	4.03	2.16
Pea Seed	0	21.85	21.85	2.70	1.57	1.72
Grain	0	17.17	17.17	2.12	1.57	1.35

TABLE 58. SEDIMENT POND SIZE AND EXCAVATION COST ESTIMATES FOR PONDS FOR 8.1-HECTARE FIELDS

Crop	Pond Size (m^3)	Excavation Cost (@ $\$0.75/m^3$) ($)	Percent of Pond Filled in One Year
Beans, Beets, Corn Seed	72	54.00	50
Potatoes	200	150.00	100
Grain, Peas	45	33.75	30
Alfalfa Hay	17	12.75	25

TABLE 59. ANNUAL OPERATING COSTS FOR SEDIMENT PONDS FOR 8.1-HECTARE FIELDS

Crop	Excavation and Spreading Costs-Pond Filled with Sediment ($)	Percent of Pond Filled in One Year	Annual Operating Costs ($)
Beans, Beets, Corn Seed	108.00	50	54.00
Potatoes	300.00	100	300.00
Grain, Peas	67.50	30	20.25
Alfalfa Hay	25.50	25	6.38

To compute the costs associated with taking land out of production for a sediment pond, the surface area of the pond was tripled to allow for margins around it. This area was then multiplied by the value of output given up on a cropped area of that size. Once again, row crop yields on these areas were assumed to be 20 percent below field averages. Table 60 shows the opportunity costs of the land taken out of production. The total annual costs for sediment ponds are presented in Table 61.

Mini-Basins - In this analysis, it was assumed that the land area taken out of production for mini-basins would be the same as the area taken out by vegetative strips. Thus, the opportunity cost for the two cases would be the same. It was also assumed that the berm along the drain ditch bank would have to be shaped and seeded every five years. The cost of this operation for a

TABLE 60. OPPORTUNITY COST OF LAND TAKEN OUT OF PRODUCTION FOR SEDIMENT PONDS FOR 8.1-HECTARE FIELDS

Crop	Net Return Given Up ($/ha)	Land Area Lost (ha)	Opportunity Cost of Land Taken Out of Production ($)
Dry Beans	334	0.018	6.00
Bean Seed	688	0.018	12.38
Corn Seed	477	0.018	8.59
Sugarbeets	504	0.018	9.07
Potatoes	714	0.038	27.13
Pea Seed	592	0.010	5.92
Winter Wheat	381	0.010	3.81
Spring Wheat	331	0.010	3.31
Alfalfa Hay	257	0.006	1.54

300-m length of ditch bank is given in Table 62.

Maintaining mini-basins would involve spreading deposited sediment and rebuilding the field berms every year on row crops and every other year on grain and peas. For alfalfa, basins put in before establishment of the alfalfa would serve for the duration of the stand. Basin construction costs are shown in Table 63. The machine labor and shovel work costs shown in this table are based on machine labor and shovel work times of 0.1 and 0.2 hours per basin, respectively, and a labor cost of $3.00 per hour.

Since mini-basins retain 1.8 times as much sediment as vegetative strips do for a given field and crop, sediment spreading costs for the basins were assumed to be 1.8 times those for strips. Sediment spreading costs for the basins are shown in Table 64. Total annual costs for the mini-basins are given in Table 65. The operating costs are the sum of the cost of shaping and seeding the ditch berm (Table 62), the basin constructions costs (Table 63) and the sediment spreading costs (Table 64).

Sprinkler Irrigation - Any large scale conversion of surface-irrigated lands to sprinklers would have many impacts that are beyond the scope of this paper. The availability of power for pumping could be a major constraint in some areas. Even so, it might be useful to look at the costs of installing and operating a sprinkler system for comparison with the costs of other methods of reducing sediment loss. In making this analysis, it was assumed

TABLE 61. TOTAL ANNUAL COSTS ASSOCIATED WITH SEDIMENT PONDS FOR 8.1-HECTARE FIELDS

Crop	Opportunity Cost of Land Taken Out of Production ($)	Operating Costs ($)	Total Costs		Sediment Retained (t/ha)	Cost of Sediment Retained ($/t)
			Whole Field ($)	Per Hectare ($)		
Dry Beans	6.00	54.00	60.00	7.41	5.38	1.38
Bean Seed	12.38	54.00	66.38	8.20	5.38	1.52
Corn Seed	8.59	54.00	62.59	7.73	5.38	1.44
Sugarbeets	9.07	54.00	63.07	7.79	5.38	1.45
Potatoes	27.13	300.00	327.13	40.39	26.89	1.50
Pea Seed	5.92	20.25	26.17	3.23	2.10	1.54
Winter Wheat	3.81	20.25	24.06	2.97	2.10	1.41
Spring Wheat	3.31	20.25	23.56	2.91	2.10	1.39
Alfalfa Hay	1.54	6.38	7.92	0.98	0.60	1.63

TABLE 62. COST OF SHAPING AND SEEDING DITCH BERMS FOR MINI-BASINS

Labor: 5 hr x \$3.00/hr ÷ 5 years =	\$3.00/year
Machine variable costs for tractor, "V" ditcher and blade: 2.5 hr x \$2.00 hr ÷ 5 years =	\$1.00/year
Grass seed:	
(area seeded - 300 m x 0.08 m = 240 m^2)	
240 m^2 ÷ 61.5 m^2/kg of seed = 4.0 kg	
4.0 kg x \$2.20/kg ÷ 5 years =	\$1.76/year
	\$5.76/year

that sprinkler systems would be designed and operated so as to eliminate runoff and sediment losses from fields.

Cost estimates were computed for a side-roll sprinkler system, as shown in Table 66. The system consists of a pump taking water out of a pond, a mainline and six laterals for 56.7 hectares of irrigated crops on a quarter section of land. Depreciation was calculated on a straight-line basis, with a useful life of 15 years for all components and a salvage value of 10 percent per year on the average investment, which is defined by the formula:

$$\text{Average Investment} = \frac{\text{New Price + Salvage Value}}{2}$$

The annual depreciation and interest cost of the system would be \$69.00 per hectare. The costs of power and repairs amount to \$3.70 and \$2.50 per irrigation per hectare, respectively.

Table 67 shows the labor cost savings that would result from converting the surface irrigation system to a side-roll sprinkler system. Ditch maintenance work would be reduced to one-third its present level (the remaining time would be spent on the pond and supply ditch and on maintaining the pipe system and controlling weeds along the mainlines). Irrigation labor, which is valued at \$3.00 per hour, would be reduced by 0.25 hours per hectare per irrigation. Machine labor savings result from the elimination of operations like land planing and corrugating that do not have to be performed with sprinkler irrigation. There would be no savings in the case of potatoes since they are hilled under both methods of irrigation.

In Table 68, the total costs (net of labor savings) of owning and operating the sprinkler system are presented for each crop. The cost of sediment retention is also shown.

TABLE 63. BASIN CONSTRUCTION COSTS FOR MINI-BASINS ON 8.1-HECTARE FIELDS

Crop	Furrow Spacing (m)	Number of Furrows per Basin	Number of Basins on 300 m of Ditch	Machine Labor Cost ($)	Shovel Work Cost ($)	Machine Variable Cost ($)	Total Berm Construction Costs Each Time ($)	Total Berm Construction Costs Annual ($)
Beans, Beets	1.12	4	67	20.10	40.20	13.40	73.70	73.70
Corn	0.76	4	99	29.70	59.40	19.80	108.90	108.90
Potatoes	0.91	4	82	24.60	49.20	16.40	90.20	90.20
Grain, Peas	0.76	6	66	19.80	39.60	13.20	72.60	36.20
Alfalfa Hay	0.76	6	66	19.80	39.60	13.20	72.60	--[1]

[1] Annual Cost = $72.60 ÷ years of stand

TABLE 64. SEDIMENT SPREADING COSTS FOR MINI-BASINS ON 8.1-HECTARE FIELDS

Crop	Cost
Beans, Beets, Corn	$53.95
Potatoes	74.92
Grain, Peas	26.96
Alfalfa Hay	7.74

Summary

The sediment loss reduction practices considered in this study showed a wide variation in cost effectiveness. Total annual costs per metric ton of sediment retained are shown in Table 69 for each of the practices analyzed.

Flow cutback is the most expensive method associated with surface irrigation of retaining a given amount of sediment if the sediment loss can be reduced by only 30 percent. Even with an 80 percent reduction, flow cutback is less cost effective than mini-basins on all crops except potatoes and corn seed.

On-farm sediment ponds can retain about two-thirds of the sediment loss from all of the crops considered, at a cost of less than two dollars per metric ton. On grain crops, a vegetative buffer strip compares favorably with sediment ponds on a cost effectiveness basis. However, vegetative strips generally retain less total sediment than ponds do.

Mini-basins retain more sediment than ponds or vegetative strips on a given field. However, they are also more expensive both in terms of total cost and the cost per metric ton of sediment retention.

Converting a surface irrigation system to a side-roll sprinkler system would eliminate surface runoff and sediment losses from a farm but would involve a large increase in costs over those associated with the use of other control practices. Potatoes are an exception since the amount of sediment loss from surface-irrigated potato fields is usually much greater than the loss from other surface-irrigated crops. For other row crops, sprinklers would cost about ten times as much per unit of sediment retained as would sediment ponds and four times as much as mini-basins. On grain, sprinklers would cost about eighteen times as much per unit of sediment retained as ponds and about six times as much as mini-basins.

FARM INCOME IMPLICATIONS OF SEDIMENT LOSS REDUCTION

The costs of employing practices such as those considered in this study to reduce sediment losses from irrigated fields can also be discussed in terms of their effects on farm income. In this sub-section, the previously discussed farm models are used to describe how sediment loss control would

TABLE 65. TOTAL ANNUAL COSTS ASSOCIATED WITH MINI-BASINS ON 8.1-HECTARE FIELDS

Crop	Opportunity Cost of Land Taken Out of Production ($)	Operating Costs ($)	Total Costs Whole Field ($)	Total Costs Per Hectare ($)	Sediment Retained (t/ha)	Cost of Sediment Retained ($/t)
Dry Beans	24.45	133.46	157.86	19.49	7.26	2.68
Bean Seed	50.36	133.41	183.77	22.69	7.26	3.13
Corn Seed	34.92	168.61	203.53	25.13	7.26	3.46
Sugarbeets	36.90	133.41	170.31	21.03	7.26	2.90
Potatoes	52.26	170.88	223.14	27.55	10.09[1]	2.73
Pea Seed	50.65	69.02	119.67	14.77	2.82	5.24
Winter Wheat	27.89	69.02	96.91	11.96	2.82	4.24
Spring Wheat	24.23	69.02	93.25	11.51	2.82	4.08
Alfalfa Hay (2-yr stand)	18.81	37.70	56.51	6.98	0.81	8.62

[1] Because of the large volume of sediment involved, basins on a potato field would probably fill up before the season ended. For purposes of comparison, it was assumed that 25 percent of the incoming sediment would be retained.

TABLE 66. ANNUAL FIXED COSTS OF A SIDE-ROLL SPRINKLER SYSTEM FOR 56.7 HECTARES OF LAND

Item	Investment Cost ($)	Annual Depreciation ($/yr)	Annual Interest ($/yr)
Laterals	27,000	1,620	1,188
Mainline	6,600	396	290
50 HP Pump	3,500	210	154
Pond	500	33	20
	37,600	2,259	1,652

TABLE 67. LABOR COST SAVINGS RESULTING FROM THE CONVERSION OF A SURFACE IRRIGATION SYSTEM TO A SIDE-ROLL SPRINKLER SYSTEM

		Labor Cost Savings			
Crop	Number of Irrigations	Ditch Maintenance ($/ha)	Irrigation ($/ha)	Machine Labor ($/ha)	Total ($/ha)
Dry Beans	7	7.25	5.25	7.62	20.12
Bean Seed	8	7.25	6.00	7.62	20.87
Corn Seed	7	7.25	5.25	5.74	18.24
Sugarbeets	10	7.25	7.50	8.34	23.09
Potatoes	12	7.25	9.00	0	16.25
Peas	5	7.25	3.75	3.60	14.60
Winter Wheat	5	7.25	3.75	3.60	14.60
Spring Wheat	4	7.25	3.00	3.60	13.85
Alfalfa Hay	6	7.25	4.50	3.60	15.35

TABLE 68. COSTS OF OWNING AND OPERATING A SIDE-ROLL SPRINKLER SYSTEM RELATIVE TO SEDIMENT RETENTION

Crop	Number of Irrigations	Power Cost ($/ha)	Repair Cost ($/ha)	Labor Cost Savings ($/ha)	Depreciation and Interest ($/ha)	Net Annual Cost ($/ha)	Sediment Retained (t/ha)	Cost of Sediment Retained ($/t)
Dry Beans	7	25.90	17.50	20.12	69.00	92.28	8.07	11.43
Bean Seed	8	29.60	20.00	20.87	69.00	97.73	8.07	12.11
Corn Seed	7	25.90	17.50	18.24	69.00	94.16	8.07	11.67
Sugarbeets	10	37.00	25.00	23.09	69.00	107.91	8.07	13.37
Potatoes	12	44.40	30.00	16.25	69.00	127.15	40.34	3.15
Peas	5	18.50	12.50	14.60	69.00	85.40	3.14	27.20
Winter Wheat	5	18.50	12.50	14.60	69.00	85.40	3.14	27.20
Spring Wheat	4	14.80	10.00	13.85	69.00	79.95	3.14	25.46
Alfalfa Hay	6	22.20	15.00	15.35	69.00	90.85	0.90	100.94

TABLE 69. COST EFFECTIVENESS SUMMARY FOR SELECTED SEDIMENT LOSS CONTROL PRACTICES[1]

Crop	Vegetative Strip	Sediment Ponds	Mini-Basins	Flow Cut-Back		Side-Roll Sprinkler
				30% Retention	80% Retention	
Dry Beans	1.77	1.38	2.68	8.68	3.26	11.43
Bean Seed	2.57	1.52	3.13	9.92	3.72	12.11
Corn Seed	2.10	1.44	3.46	8.68	3.26	11.67
Sugarbeets	2.16	1.45	2.90	12.40	4.65	13.37
Potatoes	--	1.50	2.73	2.98	1.12	3.15
Pea Seed	1.72	1.54	5.24	15.96	5.98	27.20
Winter Wheat	1.35	1.41	4.24	15.96	5.98	27.20
Spring Wheat	1.35	1.39	4.08	12.77	4.78	25.46
Alfalfa	--	1.63	8.62	66.67	25.00	100.94

[1] All figures are in dollars per metric ton of sediment retained

affect the net returns to land and management (used as a measure of net farm income) on representative farms in each study area.

Small Farm Models

Relationships between the level of sediment loss and the net returns to land and management for the small farm models are presented in Figures 38, 39, 40 and 41. Points A through E in each of these figures correspond to the sediment loss control practices or devices used on that particular farm model. In each case, the points represent the data given in Tables 70, 71, 72 and 73, respectively, for the basic crop rotation (first row of data for each practice). The sediment loss and net returns to land and management with typical current management practices and crop mixes is shown as point A in each figure. Adjustments to a sediment loss constraint set at some level lower than point A are different for each farm model and are described in the following paragraphs.

The cost curves presented in Figures 38 through 41 (right ordinate) show the annual cost of sediment loss control for each farm model. In this case, points A through E represent the reductions in net returns to land and management resulting from the use of the corresponding sediment loss control practices or devices.

The data in each table indicate what happens to the net returns to land and management as the crop mix is adjusted to meet a sediment loss constraint. In each case, it was assumed that no land is retired from irrigated crop production. Two of the small farm models include a grain crop on which a vegetative strip could be used instead of a sediment pond to control losses. On grain, vegetative strips are more cost effective than sediment ponds even though they do not remove as much sediment. Since it was assumed that there would be no runoff or sediment loss from sprinkler-irrigated fields, it was not necessary to change the crop mix for sprinklers.

Twin Falls Area - As shown in Table 70, the total sediment loss from the small farm model for the Twin Falls area with present management practices is 300 metric tons. This corresponds to point A in Figure 38. If a sediment loss limit were set at a level between points A and C, the farm operator's most efficient response (from a sediment loss control standpoint) would be to put in enough sediment ponds to meet the constraint. All fields would have sediment ponds at point C.

If the sediment loss were to be limited to a level between points C and D, the farmer would have to use sediment ponds on some fields and mini-basins on others. At point D, all fields would have mini-basins.

A sediment loss constraint set below 30 metric tons (point D) would cause some crop mix adjustment. For example, changing the crop mix to include only alfalfa hay would reduce the sediment loss to 5 metric tons for the mini-basin control practice (see Table 70). To reduce the sediment loss below about 20 metric tons, the least-cost method would be to convert the farm to sprinkler irrigation and go back to the original crop mix. For each of the farm models, it was assumed that the conversion to sprinklers would

TABLE 70. CROP MIX, SEDIMENT LOSS AND RETURNS TO LAND AND MANAGEMENT DATA FOR ALTERNATIVE CONTROL PRACTICES, TWIN FALLS SMALL FARM MODEL

	Crop Mix (Hectares)					
Control Practices	Dry Beans	Bean Seed	Pea Seed	Alfalfa Hay	Sediment Loss (t)	Net Returns to Land and Management ($)
No Sediment Control	8.1	24.3	8.1	16.2	300	38,400
		24.3	8.1	24.3	245	38,000
			8.1	48.6	70	18,700
				56.7	50	16,200
Vegetative Strips	8.1	24.3	8.1	16.2	160	38,100
		24.3	8.1	24.3	135	36,800
			8.1	48.6	55	18,600
				56.7	50	16,200
Sediment Ponds	8.1	24.3	8.1	16.2	100	38,100
		24.3	8.1	24.3	80	36,800
			8.1	48.6	25	18,600
				56.7	17	16,200
Mini-Basins	8.1	24.3	8.1	16.2	30	37,500
		24.3	8.1	24.3	25	36,200
			8.1	48.6	7	18,200
				56.7	5	15,800
Sprinklers	8.1	24.3	8.1	16.2	0	33,100

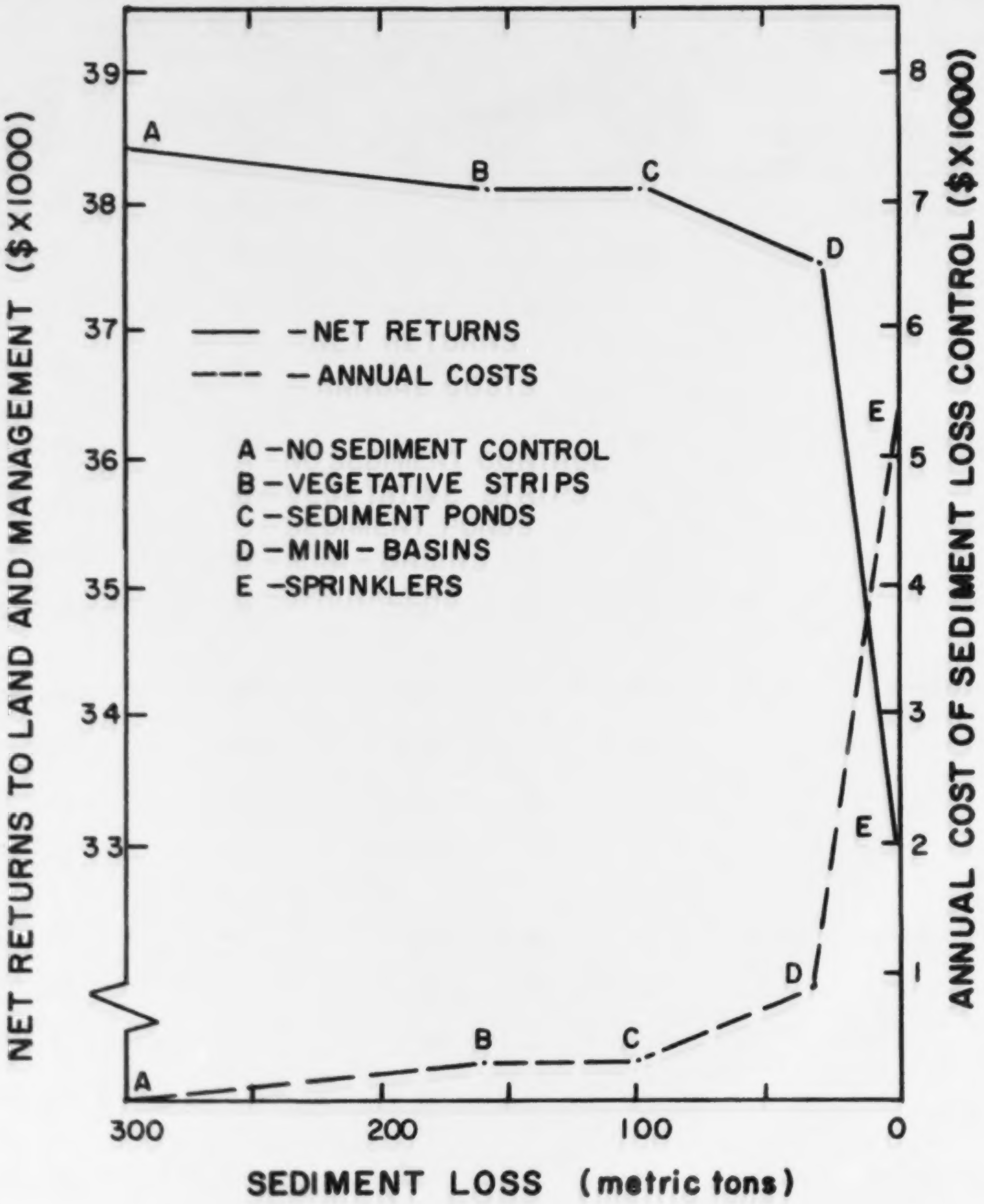

Figure 38. Returns to land and management and costs associated with different levels of sediment loss, Twin Falls small farm model.

not be gradual; that is, that either none of the fields would be sprinkler irrigated or all of them would be.

Assumptions regarding the crop mix affect the results obtained for each farm model. In this case, the maximum allowable area devoted to bean seed was assumed to be 24.3 hectares. It was further assumed that the maximum for pea seed would be 8.1 hectares and that the minimum allowable area for alfalfa hay would be 16.2 hectares.

The annual cost of sediment loss control (reduction in net farm income) versus the level of sediment loss for this farm model is shown as a cost curve in Figure 38. The annual sediment loss from this farm model could be reduced from about 300 to 100 metric tons at a rather modest cost ($300 per year) by using sediment ponds. It could be reduced by 90 percent by using mini-basins at a cost of $900 per year. Reducing the annual loss below about 20 metric tons would require the use of sprinkler irrigation which would be quite costly. In this case, the use of side-roll systems would reduce the return to land and management by $5,300 per year, a reduction of about 14 percent.

Jerome Area - The data in Table 71 show that farm income and sediment loss values for the Jerome farm model are less than those for the Twin Falls farm model. With present management practices, the sediment loss from the Jerome farm is 205 metric tons (point A in Figure 39).

If a sediment loss constraint were set at a level between points A and C, the farm operator could put in sediment ponds (or vegetative strips on the spring wheat) to meet the constraint. Sediment ponds would have to be used on all fields to meet a limit of 65 metric tons (point C). To meet a sediment loss limit set between points C and D, some fields would have sediment ponds and others would have mini-basins. At point D, all fields would have mini-basins.

A sediment loss limit set below 20 metric tons (point D) would cause some crop mix adjustment, or force a conversion to sprinklers. As shown in Table 71, the sediment loss could be reduced to 5 metric tons if the only crop grown with mini-basins is alfalfa. Further reductions in sediment loss might be attained by retiring land from production, but the farm operator would be more likely to install sprinklers or sell his farm (depending on his financial situation). For this farm model, beans were constrained to a maximum area of 16.2 hectares and the minimum alfalfa area was set at 24.3 hectares.

The reduction in farm income associated with sediment loss control for the Jerome farm model is shown by the cost curve in Figure 39. Starting at the present level of sediment loss (point A), the first increments of reduction have a relatively low cost. Reducing the loss to less than 5 metric tons would imply a reduction in net farm income of $5,000, a decrease of about 27 percent.

Wilder-Parma Area - Data for the small farm for the Wilder-Parma area are given in Table 72. As can be seen, potatoes are included in the crop

TABLE 71. CROP MIX, SEDIMENT LOSS AND RETURNS TO LAND AND MANAGEMENT DATA FOR ALTERNATIVE CONTROL PRACTICES, JEROME SMALL FARM MODEL

Control Practice	Crop Mix (Hectares)			Sediment Loss (t)	Net Returns to Land and Management ($)
	Dry Beans	Spring Wheat	Alfalfa Hay		
No Sediment Control	16.2	16.2	24.3	205	18,400
		32.4	24.3	125	17,300
			56.7	50	14,700
Vegetative Strips	16.2	16.2	24.3	115	18,200
		32.4	24.3	75	17,200
			56.7	50	14,700
Sediment Ponds	16.2	16.2	24.3	65	18,200
		32.4	24.3	40	17,200
			56.7	17	14,700
Mini-Basins	16.2	16.2	24.3	20	17,700
		32.4	24.3	13	16.700
			56.7	5	14,300
Sprinklers	16.2	16.2	24.3	0	13,400

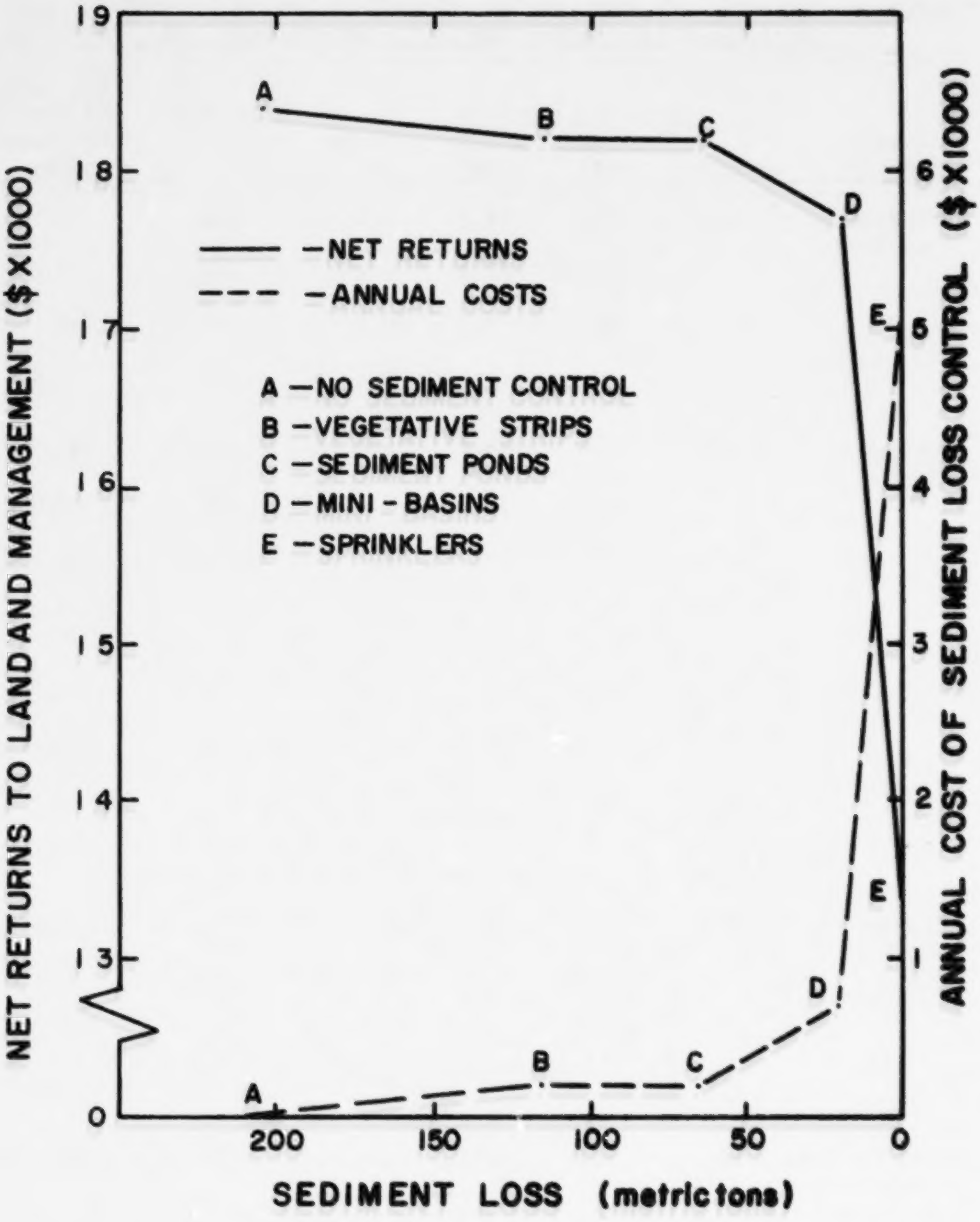

Figure 39. Returns to land and management and costs associated with different levels of sediment loss, Jerome small farm model.

TABLE 72. CROP MIX, SEDIMENT LOSS AND RETURNS TO LAND AND MANAGEMENT DATA FOR ALTERNATIVE CONTROL PRACTICES, WILDER-PARMA SMALL FARM MODEL

Control Practice	Crop Mix (Hectares)				Sediment Loss (t)	Net Returns to Land and Management ($)
	Potatoes	Sugar-beets	Winter Wheat	Alfalfa Hay		
No Sediment Control	16.2	16.2	16.2	8.1	840	41,900
		16.2	32.4	8.1	240	27,800
		16.2		40.5	165	24,500
				56.7	50	14,600
Vegetative Strips	16.2	16.2	16.2	8.1	750	41,700
		16.2	32.4	8.1	125	27,600
		16.2		40.5	100	24,300
				56.7	50	14,600
Mini-Basins	16.2	16.2	16.2	8.1	510	40,900
		16.2	32.4	8.1	25	27,000
		16.2		40.5	17	23,800
				56.7	5	14,200
Sediment Ponds	16.2	16.2	16.2	8.1	280	40,900
		16.2	32.4	8.1	80	27,500
		16.2		40.5	55	24,300
				56.7	17	14,600
Ponds for Potatoes, Basins for Others	16.2	16.2	16.2	8.1	235	40,800
Sprinklers	16.2	16.2	16.2	8.1	0	35,900

mix for this model. Since the large volume of sediment loss from potato fields would probably fill mini-basins before the end of the irrigation season, a relatively low sediment retention efficiency (25 percent) was assumed for mini-basins for potatoes. As a result, the sediment loss for the mini-basin practice is greater than the loss for sediment ponds when potatoes are included in the rotation. The loss when sediment ponds are used for potatoes and mini-basins are used for the other crops (beets, wheat and alfalfa) is shown as point D' in Figure 40.

The unconstrained sediment loss for this farm model is 840 metric tons (point A in Figure 40). If a sediment loss constraint were set at a level between points A and C, the farm operator would have to put in sediment ponds (or vegetative strips on the wheat) in order to comply. Sediment ponds would have to be installed on all fields to meet a limit of 280 metric tons (point D). To meet a sediment loss limit between points D and D', some fields would have mini-basins and some (including all of the potato fields) would have sediment ponds. At point D', all fields except the potato fields would have mini-basins.

A sediment loss limit below 235 metric tons (point D') would cause the farmer to change the crop mix. If the farmer was required to reduce the sediment loss below about 160 metric tons, the least-cost alternative would be to install sprinklers and go back to the original crop mix. For this farm model, beets and potatoes were constrained to a maximum area of 16.2 hectares each and the minimum alfalfa area was set at 8.1 hectares.

The cost of sediment loss control for this farm model is also shown in Figure 40. The cost of reducing the loss to about 28 percent of its present level would be $1,100 which is about 2.5 percent of the present return to land and management. It would cost the farm operator $6,000 per year to reduce the loss to less than 160 metric tons through the use of sprinklers. This would result in a 15 percent reduction in the net farm income.

Nampa-Melba Area - The crop mix and other data for the small farm model for the Nampa-Melba area are given in Table 73. Although different crops are involved, the graphs of farm income and sediment control costs for this farm model (Figure 41) are similar in shape to those for the Twin Falls model. The unconstrained sediment loss for this model is 465 metric tons (point A in Figure 41). The farm operator would have to use sediment ponds to meet a sediment loss constraint of 155 metric tons (point C) and would have to use mini-basins if the constraint was set between 155 and 45 metric tons (point D).

To meet a sediment loss constraint set between points D and E, the farm operator could adjust his crop mix. As shown in Table 73 for the mini-basin practice, substituting alfalfa for the other crops would reduce the sediment loss to less than 45 metric tons for this farm model. If the sediment loss limit was set below about 30 metric tons, the farm operator's least-cost alternative would be to convert to sprinkler irrigation and go back to his original crop mix. For this model, sugarbeets and seed corn were constrained to maximum areas of 24.3 and 16.2 hectares, respectively. The minimum alfalfa area was set at 8.1 hectares.

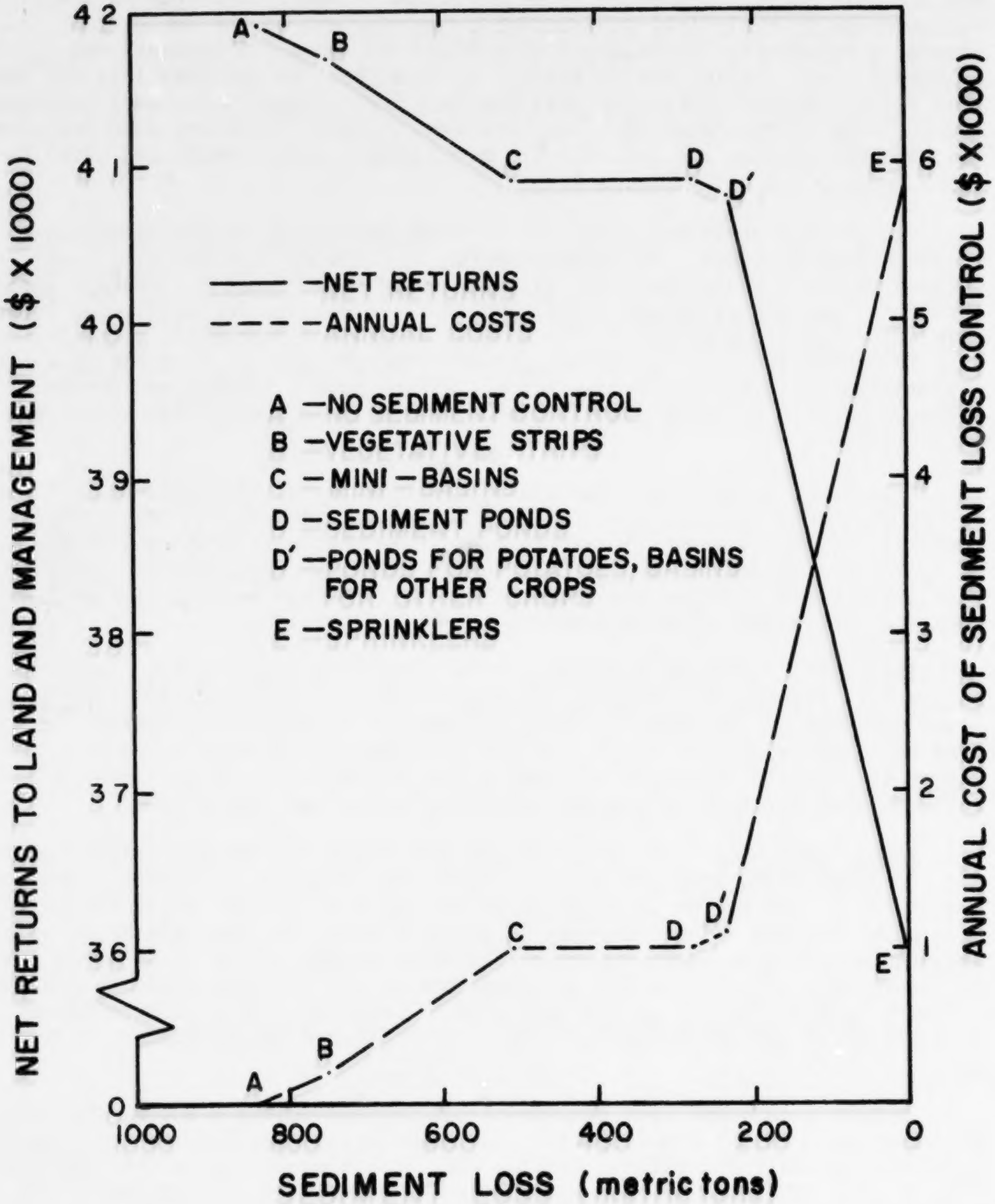

Figure 40. Returns to land and management and costs associated with different levels of sediment loss, Wilder-Parma small farm model.

TABLE 73. CROP MIX, SEDIMENT LOSS AND RETURNS TO LAND AND MANAGEMENT DATA FOR ALTERNATIVE CONTROL PRACTICES, NAMPA-MELBA SMALL FARM MODEL

	Crop Mix (Hectares)					
Control Practices	Dry Beans	Corn Seed	Sugar-beets	Alfalfa Hay	Sediment Loss (t)	Net Returns to Land and Management ($)
No Sediment Control	16.2	16.2	24.3	8.1	465	41,300
		16.2	24.3	24.3	350	39,300
			24.3	40.5	230	30,900
				64.8	60	16,700
Vegetative Strips	16.2	16.2	24.3	8.1	235	40,900
		16.2	24.3	24.3	200	38,900
			24.3	40.5	135	30,700
				64.8	60	16,700
Sediment Ponds	16.2	16.2	24.3	8.1	155	40,900
		16.2	24.3	24.3	115	39,000
			24.3	40.5	75	30,700
				64.8	20	16,700
Mini-Basins	16.2	16.2	24.3	8.1	45	40,000
		16.2	24.3	24.3	35	38,200
			24.3	40.5	25	30,100
				64.8	6	16,300
Sprinklers	16.2	16.2	24.3	8.1	0	35,000

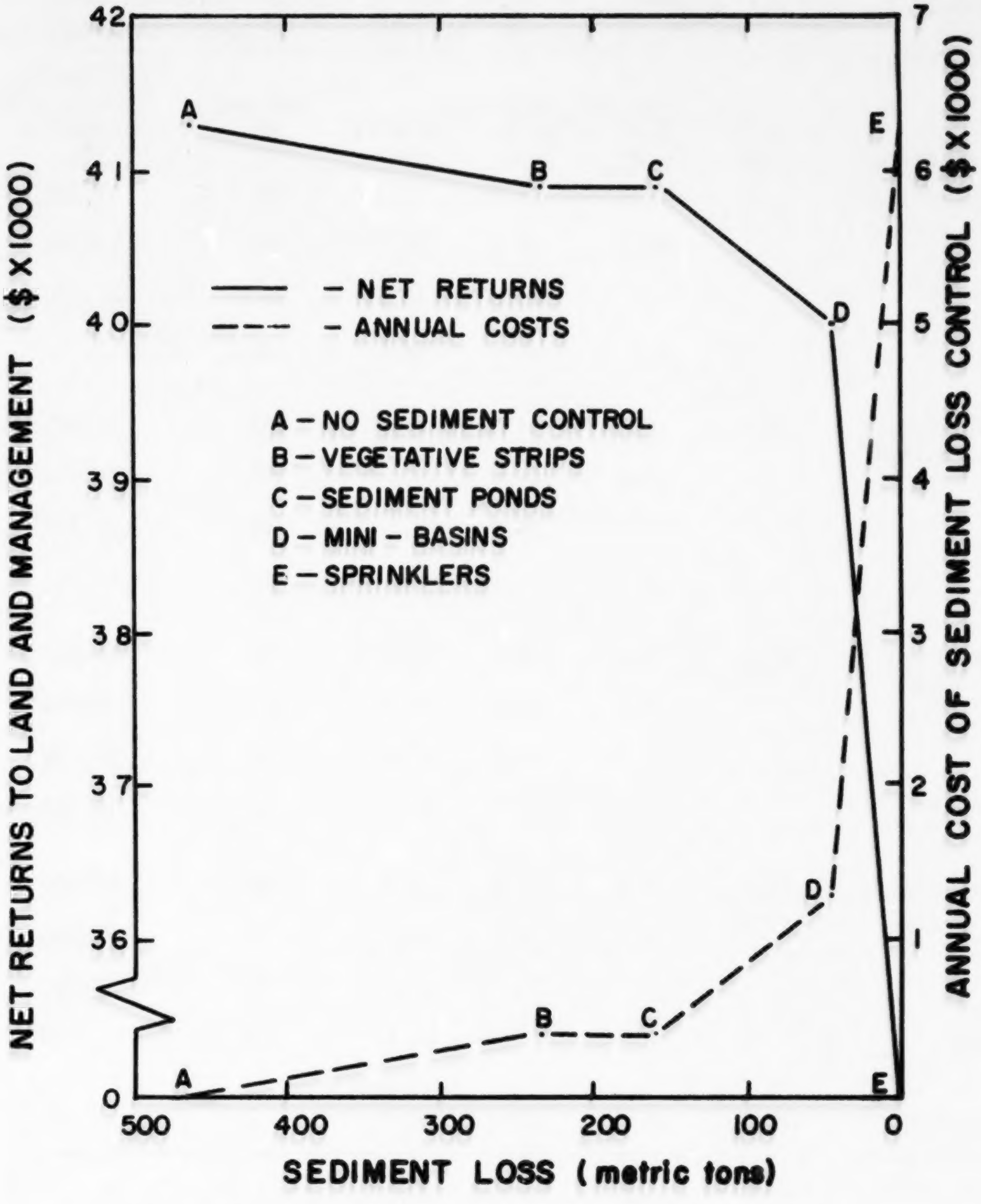

Figure 41. Returns to land and management and costs associated with different levels of sediment loss, Nampa-Melba small farm model.

Reducing the sediment loss from this farm model to less than 30 metric tons would require the use of sprinkler irrigation. This would result in a 15 percent or $6,300 reduction in net farm income (Figure 41).

Large Farm Models

Data and figures similar to those for the small farm models are presented and discussed in the following paragraphs. The points in Figures 42, 43, 44 and 45 correspond to the same sediment control practices or devices used on the small farm models. Each of the large farm models includes a grain crop on which a vegetative strip could be used to effectively control some of the sediment loss. The data for the four large farm models considered in this study are presented in Tables 74, 75, 76 and 77.

Twin Falls Area - Crop mix, sediment loss and returns to land and management data for the large farm model for the Twin Falls area are presented in Table 74. The total sediment loss from the farm with present management practicies is 615 metric tons. This loss corresponds to point A in Figure 42. If a sediment loss limit were set at a level between points A and C, the farm operator's most efficient response would be to use sediment ponds to meet the constraint. Mini-basins would have to be used if the limit were set between points C and D.

A sediment loss constraint set below 60 metric tons (point D) would cause some crop mix adjustments. Alfalfa would have to be substituted for wheat to reduce the loss to 55 metric tons, for dry beans to reduce the loss to 40 metric tons and for bean seed to reduce it to 15 metric tons. To reduce the loss below about 35 metric tons, sprinkler irrigation would have to be used along with the original crop mix.

For this farm model, pea seed was constrainted to a maximum area of 16.2 hectares, bean seed to a maximum area of 32.4 hectares and dry beans to a maximum area of 24.3 hectares. A minimum alfalfa area of 32.4 hectares was also specified.

The reduction in returns to land and management associated with sediment loss control for this farm model is shown by the cost curve in Figure 42. The first increments of sediment loss reduction are rather inexpensive. For example, the loss can be reduced to about one-third its present level at a cost of $600 per year. However, reducing the sediment loss to less than about 35 metric tons would involve a reduction in net farm income of $11,700 or 17 percent.

Jerome Area - Data for the large farm model for the Jerome area are presented in Table 75. Under present management practices, 32.4 hectares of sprinkler-irrigated potatoes are included in the crop mix. The other crops are surface irrigated.

The sediment loss from this farm under present conditions is 325 metric tons (point A in Figure 43). Adoption of sediment ponds would reduce the loss to 110 metric tons (point C). The use of mini-basins would reduce it to 35 metric tons (point D). The crop mix would have to be changed to reduce

TABLE 74. CROP MIX, SEDIMENT LOSS AND RETURNS TO LAND AND MANAGEMENT DATA FOR ALTERNATIVE CONTROL PRACTICES, TWIN FALLS LARGE FARM MODEL

	Crop Mix (Hectares)						
Control Practice	Spring Wheat	Dry Beans	Bean Seed	Pea Seed	Alfalfa Hay	Sediment Loss (t)	Net Returns to Land and Management ($)
No Sediment Control	24.3	24.3	32.4	16.2	32.4	615	70,500
		24.3	32.4	16.2	56.7	560	69,500
			32.4	16.2	81.0	385	65,500
				16.2	113.4	155	40,900
					129.6	115	36,100
Vegetative Strips	24.3	24.3	32.4	16.2	32.4	320	69,900
		24.3	32.4	16.2	56.7	305	68,900
			32.4	16.2	81.0	230	65,100
				16.2	113.4	125	40,900
					129.6	115	36,100
Sediment Ponds	24.3	24.3	32.4	16.2	32.4	205	69,900
		24.3	32.4	16.2	56.7	185	68,900
			32.4	16.2	81.0	125	65,100
				16.2	113.4	50	40,700
					129.6	40	36,000
Mini-Basins	24.3	24.3	32.4	16.2	32.4	60	68,600
		24.3	32.4	16.2	56.7	55	67,600
			32.4	16.2	81.0	40	63,900
				16.2	113.4	15	39,900
					129.6	12	35,200
Sprinklers	24.3	24.3	32.4	16.2	32.4	0	58,800

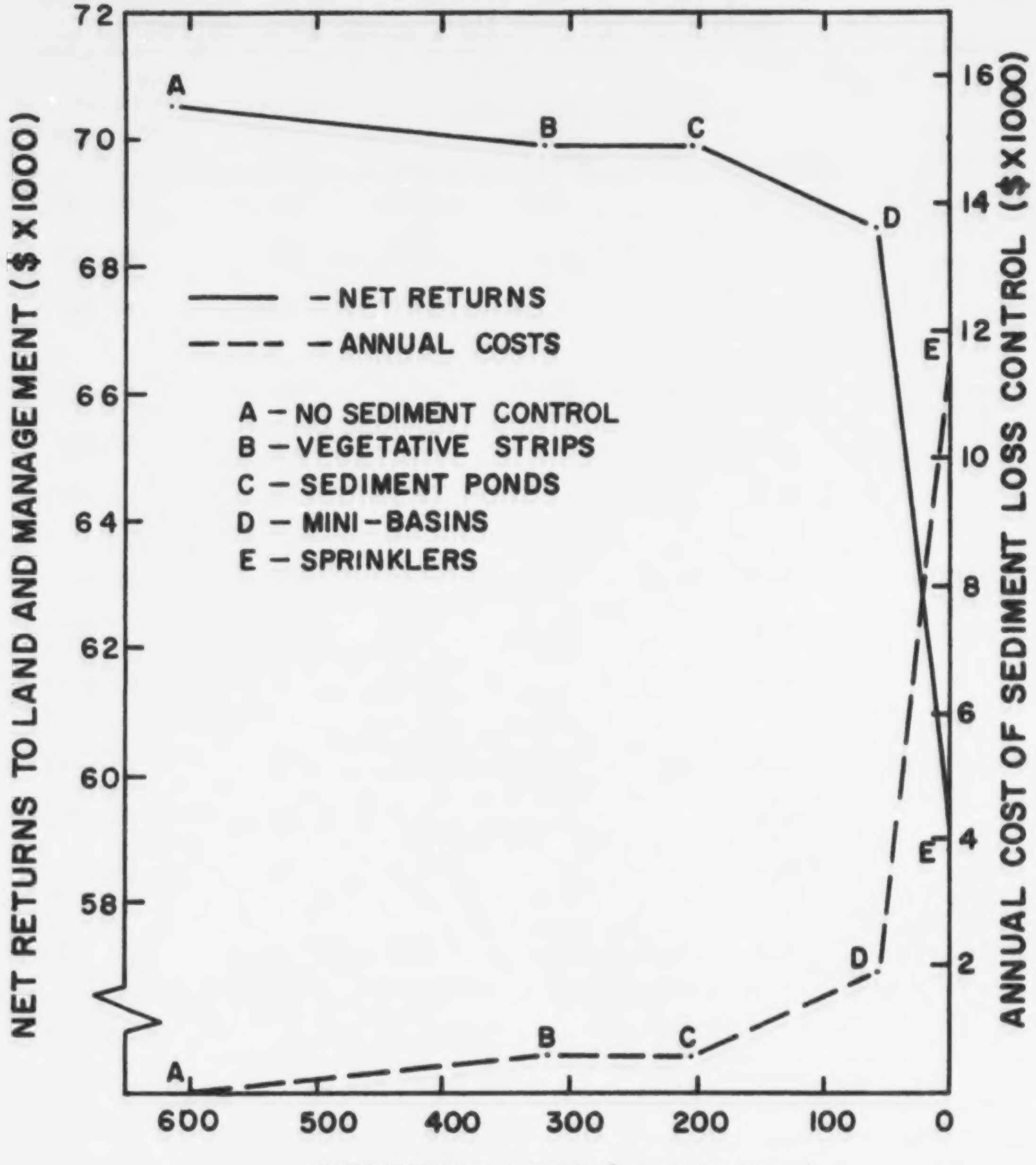

Figure 42. Returns to land and management and costs associated with different levels of sediment loss, Twin Falls large farm model.

TABLE 75. CROP MIX, SEDIMENT LOSS AND RETURNS TO LAND AND MANAGEMENT DATA FOR ALTERNATIVE CONTROL PRACTICES, JEROME LARGE FARM MODEL

Control Practice	Crop Mix (Hectares)				Sediment Loss (t)	Net Returns to Land and Management ($)
	Potatoes	Dry Beans	Spring Wheat	Alfalfa Hay		
No Sediment Control	32.4	24.3	32.4	32.4	325	69,500
	32.4		56.7	32.4	205	67,600
	32.4			89.1	90	61,700
Vegetative Strips	32.4	24.3	32.4	32.4	180	69,200
	32.4		56.7	32.4	120	67,500
	32.4			89.1	90	61,700
Sediment Ponds	32.4	24.3	32.4	32.4	110	69,200
	32.4		56.7	32.4	70	67,400
	32.4			89.1	25	61,600
Mini-Basins	32.4	24.3	32.4	32.4	35	68,400
	32.4		56.7	32.4	20	66,700
	32.4			89.1	8	61,000
Sprinklers	32.4	24.3	32.4	32.4	0	61,700

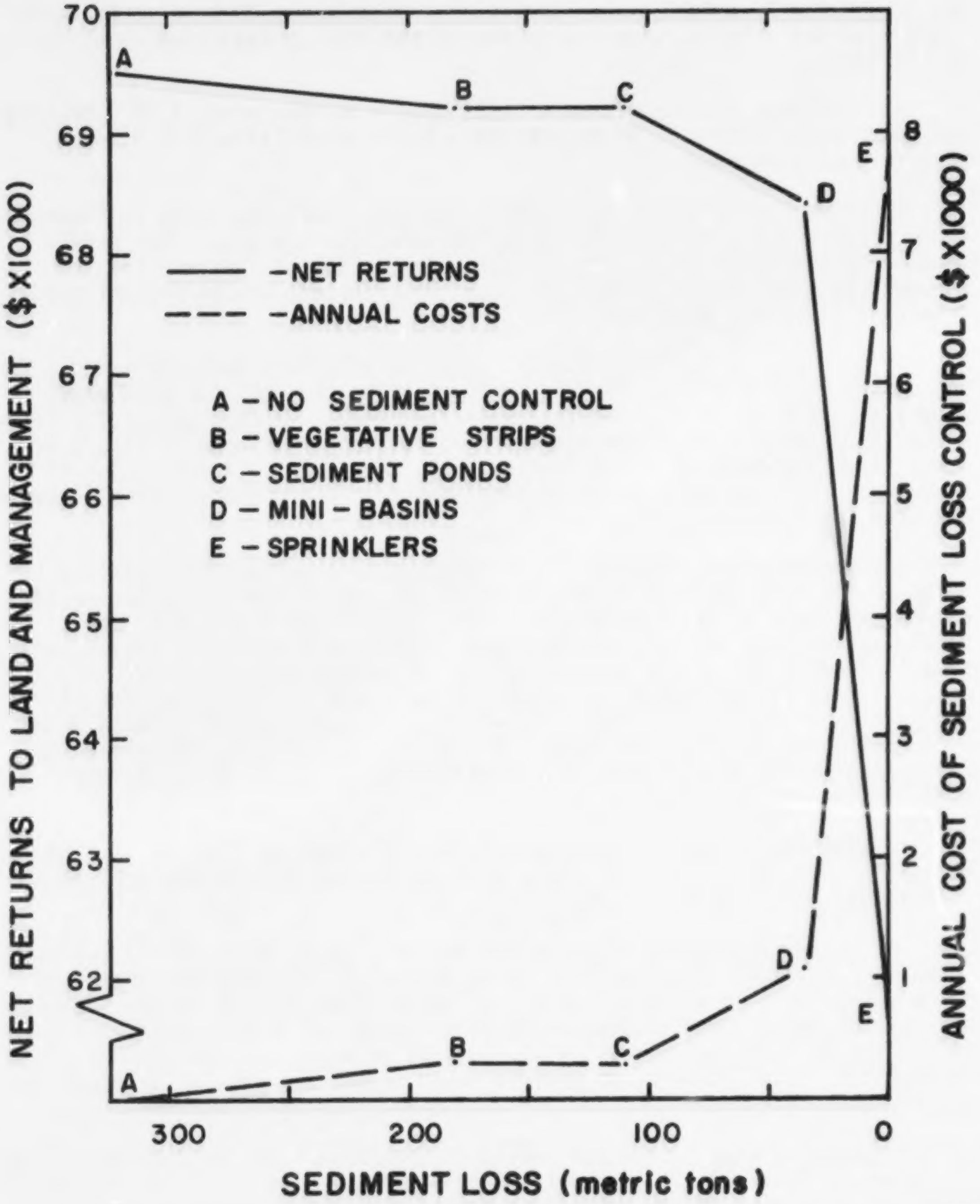

Figure 43. Returns to land and management and costs associated with different levels of sediment loss, Jerome large farm model.

the loss below 35 metric tons. Sprinkler irrigation would have to be used along with the original crop mix to reduce the loss to less than about 10 metric tons.

For this model, potatoes were limited to a maximum area of 32.4 hectares and beans were limited to 24.3 hectares. A minimum alfalfa area of 32.4 hectares was also used.

The costs of sediment loss control for this model are shown in Figure 43. These costs are low relative to the costs shown for the other farm models because part of the farm is already sprinkler irrigated. Elimination of sediment loss would cost $7,800 per year or 11 percent of the present net returns to land and management.

Wilder-Parma Area - Crop mix and other data for the large farm model for the Wilder-Parma area are given in Table 76. The crop mix for this model is almost the same as the mix for the small farm model for this area. The relationships between farm income and sediment loss control shown in Figure 44 are also very similar to those for the small farm model. Again, point D' represents the case where sediment ponds are used for potatoes and mini-basins are used for the other crops.

The sediment loss from this farm under current management practices is 1,750 metric tons (point A in Figure 44). The use of sediment ponds would reduce this loss to 580 metric tons (point D). To meet a sediment loss constraint between points D and D', some fields would have mini-basins and some (including all of the potato fields) would have sediment ponds. At point D', all fields except the potato fields would have mini-basins. A sediment loss limit set at less than 475 metric tons (point D') could be met by substituting wheat for potatoes. A limit set below about 300 metric tons would require the installation of sprinklers and a return to the original crop mix (point E).

In this case, potatoes were constrained to a maximum area of 32.4 hectares and sugarbeets were limited to 40.5 hectares. The minimum area for alfalfa was set at 32.4 hectares.

The costs of sediment loss control for this model are shown by the cost curve in Figure 44. Sediment loss could be reduced to about 28 percent of its present level at a cost of $3,100 or about three percent of the present net returns to land and management by using ponds for potatoes and mini-basins for other crops. Reducing the loss below about 300 metric tons through the installation of sprinklers would reduce the returns by about 14 percent.

Nampa-Melba Area - Data for the large farm model for the Namp-Melba area are given in Table 77. This model differs from the others in that it includes no alfalfa. The lowest sediment yield, among the crops in the model, comes from wheat.

The total sediment loss from this farm under present management practices is 925 metric tons (point A in Figure 45). This loss could be reduced

TABLE 76. CROP MIX, SEDIMENT LOSS AND RETURNS TO LAND AND MANAGEMENT FOR ALTERNATIVE CONTROL PRACTICES, WILDER-PARMA LARGE FARM MODEL

Control Practice	Crop Mix (Hectares) Potatoes	Sugar-beets	Winter Wheat	Alfalfa Hay	Sediment Loss (t)	Net Returns to Land and Management ($)
No Sediment Control	32.4	40.5	32.4	32.4	1750	98,300
		40.5	64.8	32.4	560	71,300
		40.5		97.2	410	62,700
				137.7	120	36,900
Vegetative Strips	32.4	40.5	32.4	32.4	1540	97,900
		40.5	64.8	32.4	290	70,800
		40.5		97.2	250	62,400
				137.7	120	36,900
Mini-Basins	32.4	40.5	32.4	32.4	1020	95,900
		40.5	64.8	32.4	55	69,400
		40.5		97.2	40	61,200
				137.7	12	35,900
Sediment Ponds	32.4	40.5	32.4	32.4	580	96,200
		40.5	64.8	32.4	185	70,800
		40.5		97.2	135	62,400
				137.7	40	36,800
Ponds for Potatoes, Basins for Others	32.4	40.5	32.4	32.4	475	95,200
Sprinklers	32.4	40.5	32.4	32.4	0	84,100

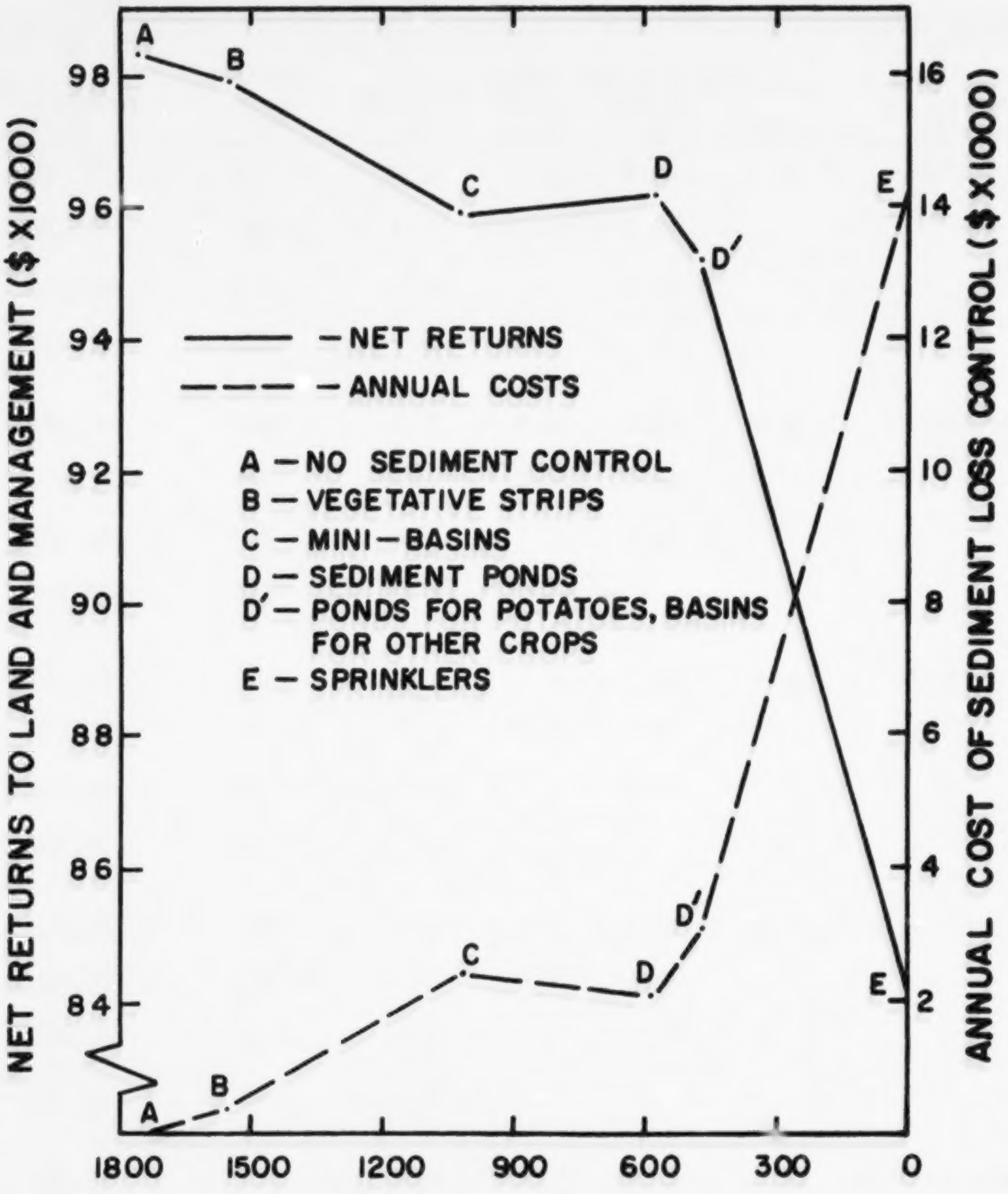

Figure 44. Returns to land and management and costs associated with different levels of sediment loss, Wilder-Parma large farm model.

TABLE 77. CROP MIX, SEDIMENT LOSS AND RETURNS TO LAND AND MANAGEMENT DATA FOR ALTERNATIVE CONTROL PRACTICES, NAMPA-MELBA LARGE FARM MODEL

	Crop Mix (Hectares)				Sediment Loss (t)	Net Returns to Land and Management ($)
Control Practices	Dry Beans	Corn Seed	Sugar-beets	Winter Wheat		
No Sediment Control	24.3	24.3	56.7	24.3	925	90,700
		24.3	56.7	48.6	805	90,400
			56.7	72.9	685	79,700
				129.6	405	51,800
Vegetative Strips	24.3	24.3	56.7	24.3	465	89,900
		24.3	56.7	48.6	405	89,600
			56.7	72.9	345	79,000
				129.6	205	51,700
Sediment Ponds	24.3	24.3	56.7	24.3	310	89,900
		24.3	56.7	48.6	270	89,700
			56.7	72.9	230	79,000
				129.6	135	51,500
Mini-Basins	24.3	24.3	56.7	24.3	95	88,100
		24.3	56.7	48.6	80	88,000
			56.7	72.9	70	77,600
				129.6	40	50,300
Sprinklers	24.3	24.3	56.7	24.3	0	78,000

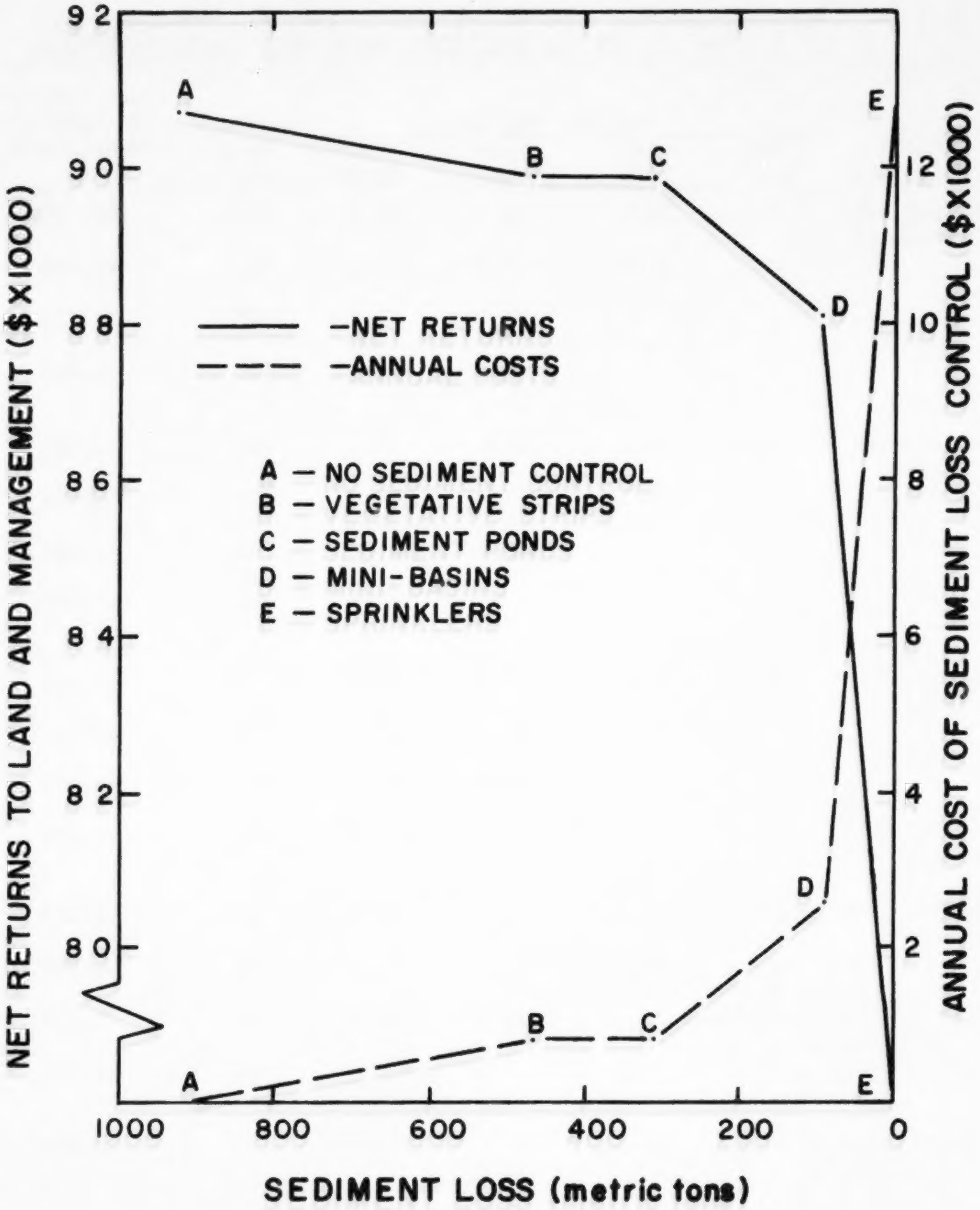

Figure 45. Returns to land and management and costs associated with different levels of sediment loss, Nampa-Melba large farm model.

to 310 metric tons by the use of sediment ponds (point C) and to 95 metric tons by the use of mini-basins (point D). The farm operator would have to change the crop mix to reduce the loss below 95 metric tons. If the farm operator were required to reduce the loss below about 70 metric tons, the least-cost method would be to convert to sprinkler irrigation and go back to the original crop mix.

For this model, sugarbeets were constrained to a maximum area of 56.7 hectares and seed corn was constrained to an area of 24.3 hectares. The minimum area of wheat was set at 24.3 hectares.

The costs of sediment loss control are shown by the cost curve in Figure 45. Like the cost curves for the other farm models, it shows that modest costs are associated with the first 70 percent decrease in sediment loss and that the costs to eliminate losses would be quite high. To reduce the sediment loss below about 70 metric tons would reduce the returns to land and management by $12,700, a decrease of 14 percent.

SUMMARY

Based on the assumptions of this study concerning the physical effectiveness of different control practices and devices, sediment losses from surface-irrigated fields can be reduced to between one-half and one-third of their present levels at a modest cost. This could be done by using on-farm sediment ponds (or vegetative buffer strips on grain) to remove the sediment from the surface runoff from fields. The costs of ponds would average $475 annually on the small farm models and $950 annually on the large farm models. As shown in Table 78, the reduction in net returns to land and management for ponds is slightly more than one percent.

Compared with sediment ponds, mini-basins increase the amount of sediment retained on the model farms for all crops except potatoes. They also increase the costs. For both sizes of farm models, the average sediment loss reduction for the mini-basins is 82 percent (from 452 to 82 metric tons for the small farm models and from 906 to 166 metric tons for the large ones). The annual costs average $1,000 and $2,175, respectively, for the two sets of farm models. These costs would lower the net returns to land and management by slightly more than 2.5 percent.

Elimination of surface runoff and sediment losses would require the use of sprinkler irrigation. This would cost an average of $5,650 annually on the small farm models and $11,600 annually on the large farm models. The resulting decrease in the net returns to land and management would be about 15 percent in both cases.

TABLE 78. SUMMARY OF SEDIMENT LOSS AND ANNUAL COST DATA

	Sediment Loss (metric tons)				Annual Costs (dollars)		
	Base	Ponds	Basins	Sprinklers	Ponds	Basins	Sprinklers
Small Farm Models							
Twin Falls	300	100	30	0	300	900	5,300
Jerome	205	65	20	0	200	700	5,000
Wilder-Parma	840	280	235[1]	0	1,000	1,100	6,000
Nampa-Melba	465	155	45	0	400	1,300	6,300
Average	452	150	82	0	475	1,000	5,650
Average decrease in net returns to land and management (%)					1.4	2.8	16.1
Large Farm Models							
Twin Falls	615	205	60	0	600	1,900	11,700
Jerome	325	110	35	0	300	1,100	7,800
Wilder-Parma	1,750	580	475[1]	0	2,100	3,100	14,200
Nampa-Melba	925	310	95	0	800	2,600	12,700
Average	906	300	166	0	950	2,175	11,600
Average decrease in net returns to land and management (%)					1.2	2.6	14.1

[1] Sediment ponds on potatoes, mini-basins on other crops

SECTION 9

OVERALL IMPACTS OF REDUCING POLLUTANT LOSSES

The general purpose of this phase of the study was to determine the overall effects of reducing pollutant losses from irrigated lands. The specific purpose was to evaluate the aggregate effects of reducing the loss of sediment and other pollutants from surface-irrigated fields in the Boise Valley. Benefits may be derived both on the farm and further downstream by programs which effectively reduce these losses. Pollutant losses from irrigated lands may result in both a physical change in water quality and an actual reduction in the well being of society. Water quality may decline, however, without an immediately apparent impact on society.

METHODOLOGY

The approach used in this phase of the study was to first identify the impacts of sediment and other pollutant losses on water quality and then to identify and quantify the economic losses (if any) that result from these losses. On-farm impacts of pollutant losses were determined by interviewing irrigators in the Boise Valley and obtaining costs incurred because of sediment and other pollutant losses. The same approach was used for irrigation districts and canal companies. Expenditures are necessary to clean and maintain canals and ditches where sedimentation occurs.

The impacts of pollutant losses on water quality were determined by studying parameters associated with irrigation (specific conductivity, suspended solids, nitrogen and phosphorus). Comparisons were made of the level of these parameters above Boise (before the water was used for irrigation or other purposes) and at Notus or Parma which are near where the Boise River flows into the Snake River. Changes in the quality of water in the Boise River due to irrigation have detrimental impacts in the Boise Valley itself as well as in the Snake River below its confluence with the Boise River. Assessing these impacts in the Snake River becomes more difficult as one moves further downstream and other streams enter the river.

WATER QUALITY

In the Boise Valley, surface water is used primarily for irrigation while groundwater supplies individual, urban and industrial needs. Some groundwater is also used for irrigation in the area.

Groundwater

Water departments in three Boise Valley cities (Boise, Meridian and Caldwell) were contacted to determine if seepage from irrigation has affected groundwater quality in the area. At the date of this report, no major groundwater users in the area have reported previous contamination of wells. The state chemist for the Idaho Department of Water Resources reported that some shallow wells had poor water quality because of poor construction. A study of groundwater quality in the Boise Valley based on 200 samples found no difference in quality between 1953 and 1970 (Dion, 1972). Consequently, it was concluded that surface irrigation has not affected groundwater quality except in the case of a few poorly constructed shallow wells. Based on the sample size and analytical methods used, one may question whether or not this study is conclusive.

Irrigation has had a major impact on water table elevations in the Boise Valley. An especially high water table exists in the lower downstream portions of the Valley. Irrigation raises groundwater levels in many valley areas in the latter part of the irrigation season. Because of this, it is necessary for the city of Meridian to run four pumps year round to reduce high groundwater levels. High groundwater levels are also a problem in the Caldwell area.

High groundwater levels also create problems when basements are dug for houses. When they become too high, sewage treatment plants may be ineffective, resulting in raw sewage being dumped back into the Boise River. Also, septic tank drainfields in the area do not function properly when groundwater levels are too high. On the other hand, high groundwater levels may result in lower pumping costs and may provide a flushing effect in drainage systems in the Valley.

Surface Water

River Flows - The purpose of the storage system on the Boise River is to spread the water supply over the growing season. The natural flow of the Boise River, monthly canal diversions and return flows from drains in the area (Musselman, 1973) are shown in Figure 46 for the 1973 growing season. The natural flow of the river rises in April, peaks in May and then declines throughout the summer months. Canal diversions are essentially constant from May through August.

Based on the data shown in Figure 46, it would be expected that the pollution from irrigation would be highest in the May through August period when canal diversions are highest. The flow in the Boise River drops off drastically as water is diverted for irrigation. This, of course, would tend to increase the concentrations of pollutants in the river.

The river water above Lucky Peak Dam (just upstream from Boise) is relatively unspoiled by human activity and consequently provides a high quality source of irrigation water for use further down the Valley. At several points in the Valley, irrigation return flows are diverted again for irrigation purposes. When the sediment load carried by these return flows is high, downstream users may suffer economic loss in order to either remove the sediment before the water is used or to clean their ditches after the irrigation season. Prevention of sediment losses on the farms where they originate would benefit downstream users.

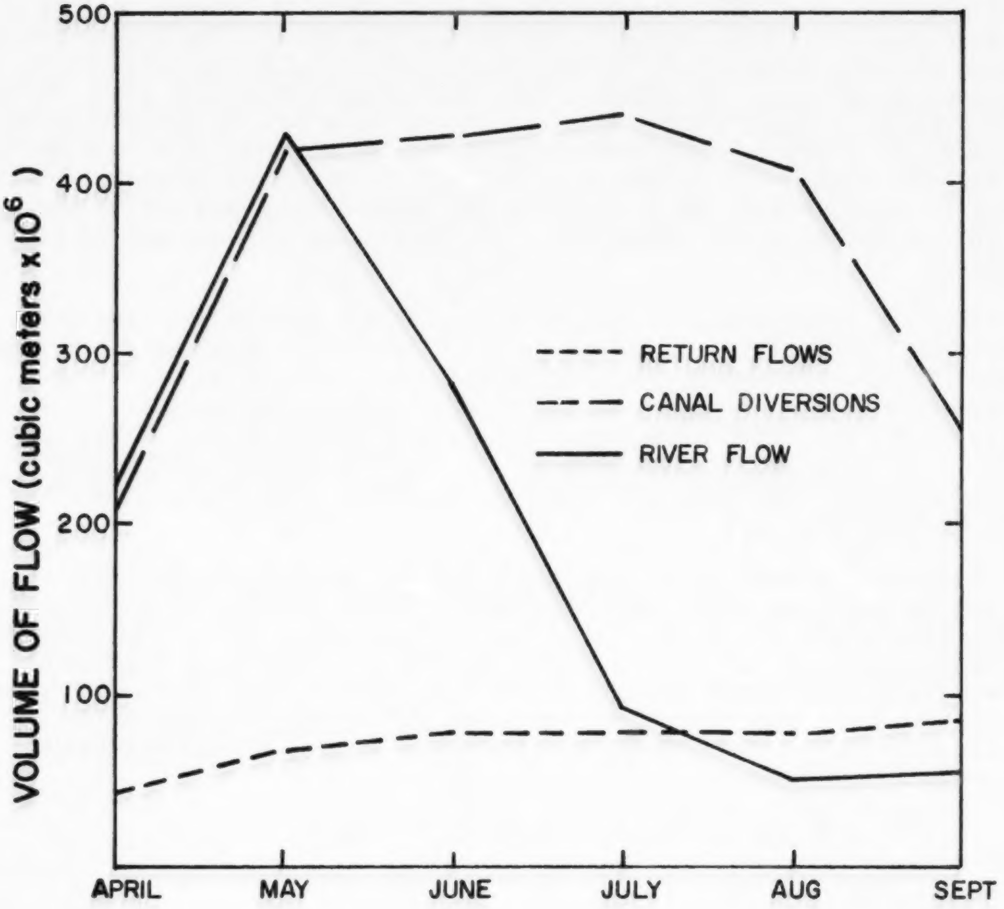

Figure 46. Natural flow of the Boise River, canal diversions and return flows during the 1973 irrigation season.

Specific Conductivity - As a measure of the salt content of water, specific conductivity offers one of the better indicators of the impact of irrigation on the quality of the water in the Boise River. Natural increases in salt concentrations are to be expected as water flows toward the sea. Since seepage and return flows from irrigated lands carry soluble salts into receiving ditches and streams, they can substantially increase salt concentrations over natural levels.

Specific conductivity readings taken at Boise and Notus during 1973 (USDI, Geological Survey, 1973) are compared in Figure 47. The average reading at Boise was 87.7 micromhos/cm as compared to an average reading of 499 micromhos/cm at Notus which is downstream from Boise. The higher average reading at Notus indicates that the salt concentration in the Boise River increases as one goes downstream. Also, the standard deviation about the mean reading was much higher at Notus than at Boise. The monthly readings shown in Figure 47 for Notus indicate that the specific conductivity is higher during the fall and winter months than it is during the irrigation season. This may be due to the fact that the river flows are lower during this period than they are during the irrigation season and groundwater contributions are relatively higher.

There is no evidence to support whether or not the salts in the Boise River water cause any economic loss in the Boise River Valley or further downstream in the Snake River. The average specific conductivity of the water at Notus, while being over five times as high as the average conductivity at Boise, is not any higher than the conductivity of water samples taken from wells in the area used for drinking water. The higher salt concentrations at Notus during the growing season are probably due to irrigation. However, they cause no known problems.

Data are available on a daily basis for the specific conductivity of Boise River water at Notus (USDI, Geological Survey, 1973). Also, data on stream discharges, diversions for irrigation and return flows from drains are available. Using a model which makes specific conductivity a function of stream discharges, diversions and return flows gave statistically significant results for all three independent variables (all three are significant at the one percent level). The results of this analysis for the 1973 irrigation season were as follows:

$$Y = 450.121 - 8.971 X_1 - 0.801 X_2 + 8.226 X_3$$

where

Y = specific conductivity in micromhos/cm

X_1= discharge in cubic meters per second

X_2= diversions in cubic meters per second

X_3= return flow in cubic meters per second

All variables are for the Boise River at Notus. The standard error for the three independent variables are 0.8566, 0.1357 and 0.9174, respectively. The corresponding t-values are -10.4734, -5.9024 and 8.9670, respectively. The

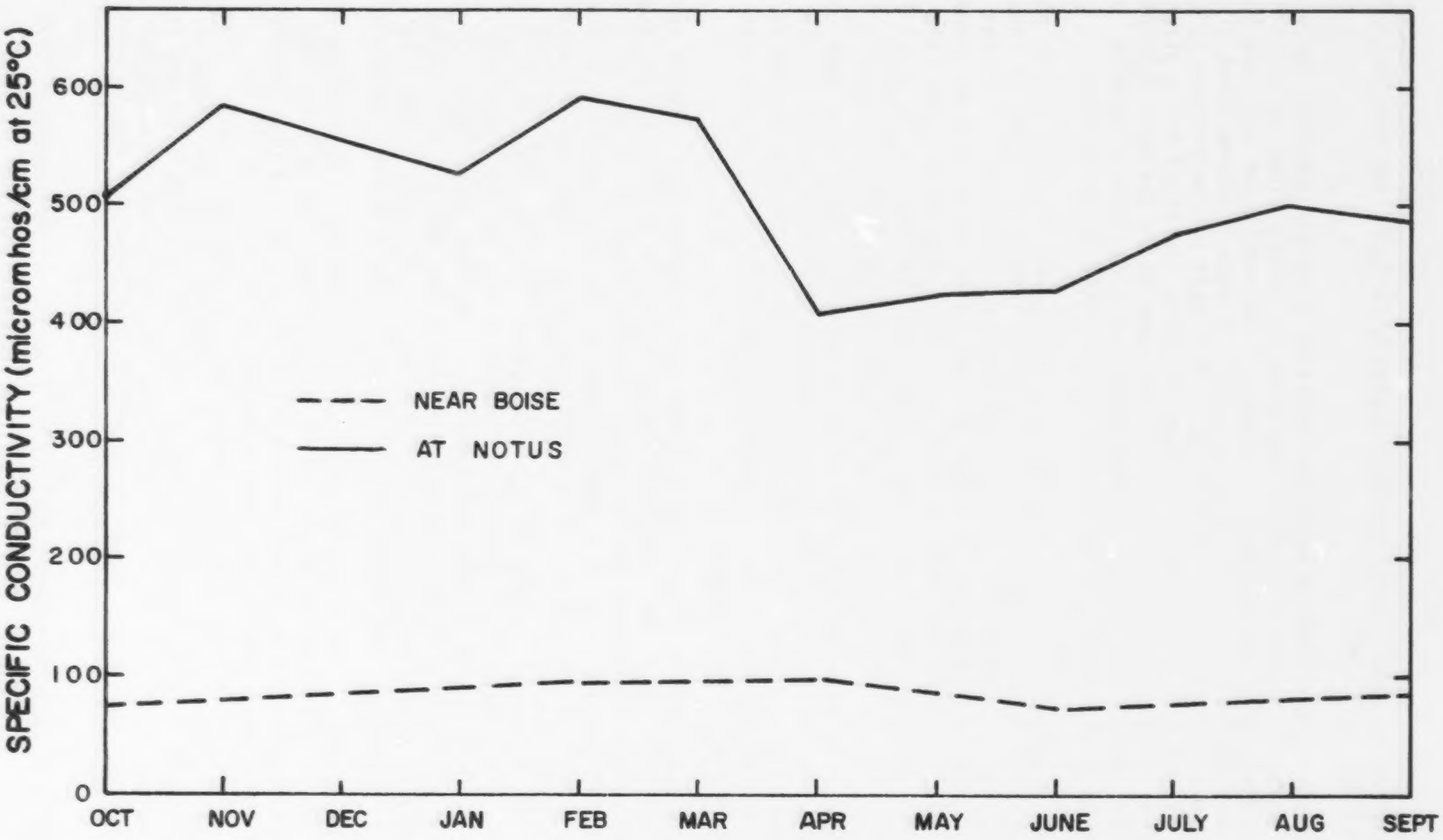

Figure 47. Specific conductivity of the Boise River near Boise and at Notus, October 1972 through September 1973.

multiple correlation coefficient for this analysis is 0.770 and the standard error of estimate is 37.847.

Essentially, the preceding equation indicates that the specific conductivity of the Boise River water at Notus increases as return flows increase and decreases as diversions and discharge increase. The conclusion that can be drawn from this analysis is that it is necessary to reduce return flows or increase discharge and diversions in order to reduce salt concentrations in the Boise River at Notus. Since the latter two variables are fixed for a given year, the control or reduction of return flows seems to be the most logical way to achieve this. This may not be entirely practical since a certain amount of salts must be leached out of the soil to keep it productive.

Nitrogen - Various forms of nitrogen may be present in water due to numerous human activities including farming. The data plotted in Figure 48 show monthly variations in dissolved nitrite plus nitrate concentrations in the Boise River below Lucky Peak Dam and near Caldwell from April 1973 to November 1976.[1] The dissolved nitrite plus nitrate concentrations below Lucky Peak Dam are substantially lower than the concentrations near Caldwell. The average concentration near Caldwell was over seven times greater than that below Lucky Peak Dam (1.09 versus 0.14 mg/l) which leads one to the conclusion that considerable nitrogen is added to the Boise River as it flows from Lucky Peak Dam to its mouth. It should not be concluded, however, that irrigation return flows are the only source of the nitrogen in the river. Sewage, feedlots, large dairy operations and pastures located adjacent to the river are also possible sources of this nitrogen.

The data presented in Figure 48 indicate that nitrite plus nitrate concentrations are higher after the irrigation season (October through March) than they are during the irrigation season (April through September). As in the case of specific conductivity, the larger flows in the river during the irrigation season probably have a dilutive effect on the groundwater that enters the stream. Nitrogen concentrations in the river water near Caldwell are not any higher than they are in many of the groundwater observations wells in the Valley. It was not determined that the nitrogen per se in the Boise River caused any economic losses in the Boise Valley or further downstream. If the population in the area continues to increase and to put additional demands on the water supply, greater controls on the sources of nitrogen in the Boise River may be necessary. Effective control measures could be very expensive.

Total Phosphorus - Total phosphorus concentrations below Lucky Peak Dam and near Caldwell are shown in Figure 49 by months from 1973 to 1976. As with the other constituents, the concentrations of total phosphorus near Caldwell were higher than those just below Lucky Peak Dam (0.28 versus 0.04 mg/l). Phosphorus concentrations in the river water were considerably higher than those of water samples taken from area wells. However, data for comparisons are scarce. There is no evidence of economic loss as the result of the increase in the concentration of total phosphorus in the Boise River between Lucky Peak Dam and Caldwell. However, nutrients and chemicals may be causing

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[1] Unpublished data, Northwest Region, U.S. Bureau of Reclamation, 1976.

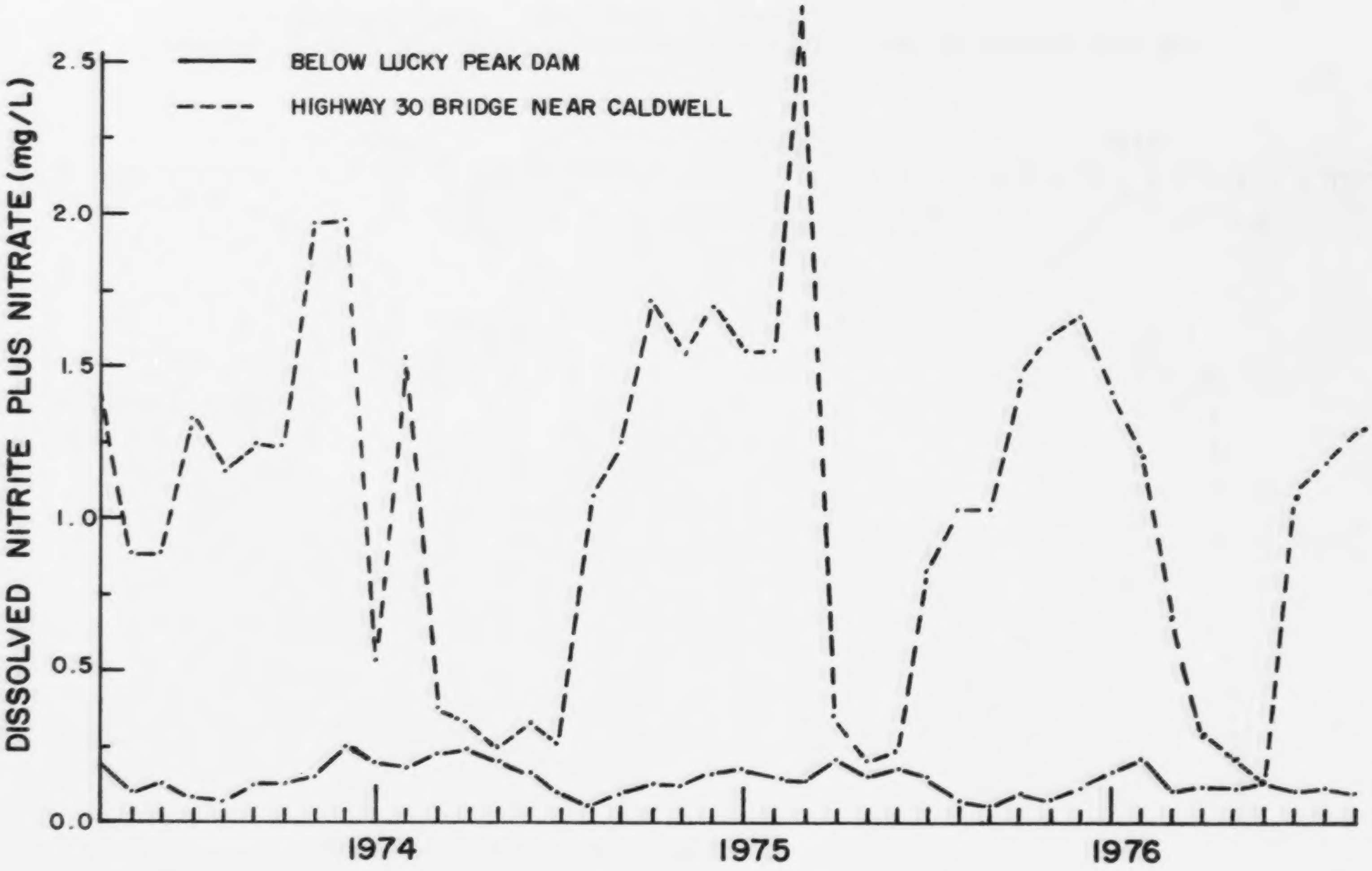

Figure 48. Dissolved nitrite plus nitrate concentrations in the Boise River below Lucky Peak Dam and near Caldwell, April 1973 to September 1976.

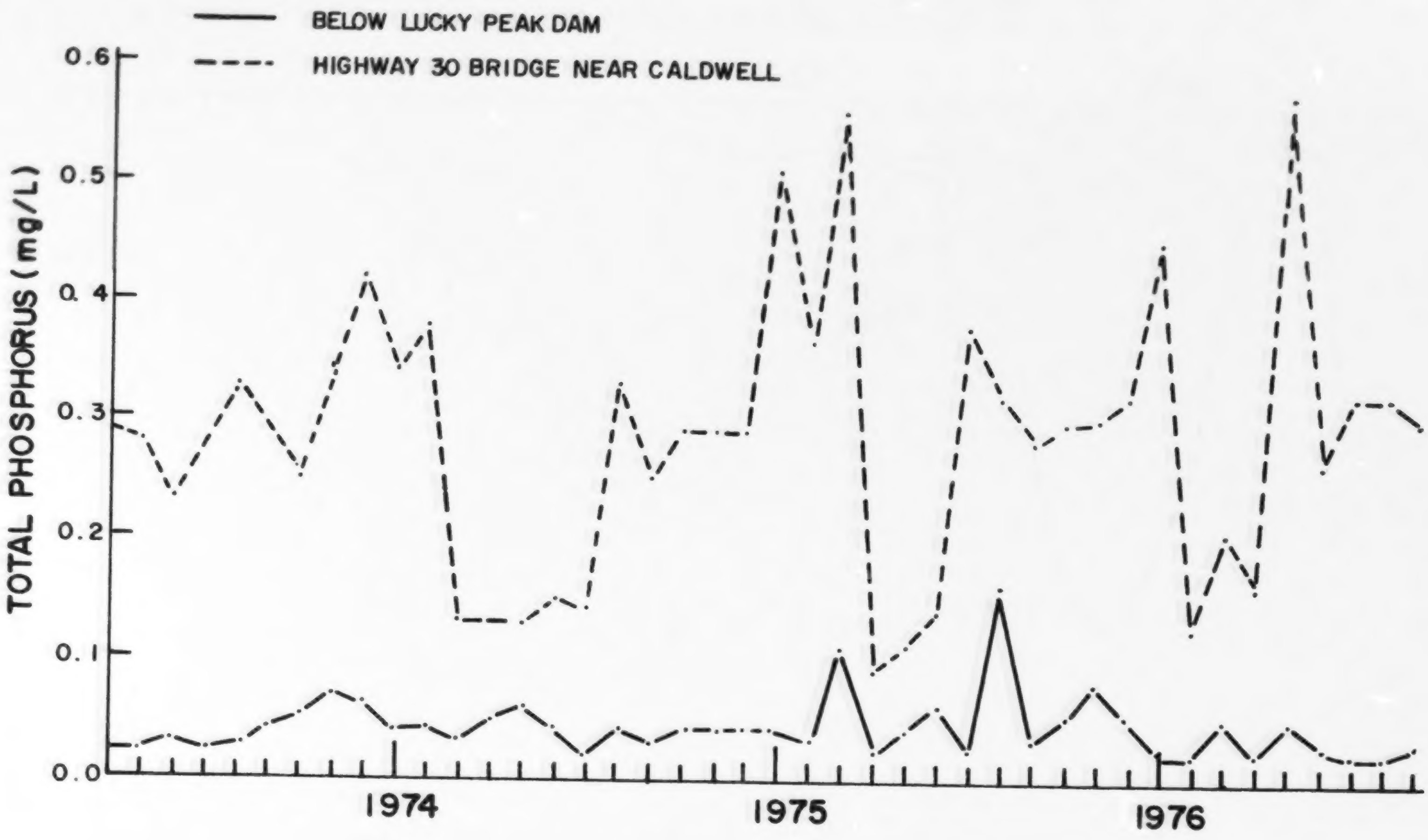

Figure 49. Total phosphorus concentrations in the Boise River below Lucky Peak Dam and near Caldwell, April 1973 to September 1976.

adverse downstream effects in Brownlee Reservoir on the Snake River (EPA, 1975).

Changes in the quality of the Boise River are apparently the result of: (1) operations which result in the addition of various materials to the river water and (2) diversions which reduce flows in the river to the point where the concentrations of nutrients and other chemical constituents become detrimental. These factors may also encourage the growth of algae which results in a loss of oxygen in the river water and less wildlife. Economic losses from these factors are not known nor have values been estimated.

Sediment - Soil losses from fields are one of the greatest pollution problems associated with surface irrigation. Both the individual farmer who loses the soil and downstream water users suffer economic losses as a result of these soil losses. Sediment concentrations in the Boise River below Lucky Peak Dam and near Caldwell are shown in Figure 50. In general, sediment concentrations below Lucky Peak Dam are lower than they are near Caldwell. However, the data show instances where the reverse is true. In 1975 and 1976, the concentrations near Caldwell were consistently higher than those below Lucky Peak Dam. During the 1975 and 1976 irrigation seasons, the sediment concentrations near Caldwell were 8 to 10 times higher than those below Lucky Peak Dam. Most of this increase is due to irrigation return flows.

As shown in Figure 51, turbidity readings taken near Caldwell are higher than those taken below Lucky Peak Dam. The readings, which are in Jackson Turbidity Units (JTU), are a measure of the amount of suspended matter in a sample of water which causes light to be scattered or absorbed rather than transmitted through a sample. Most of the peaks in the readings shown in Figure 51 for Caldwell occur during the latter part of the irrigation season. Other peaks occur at other times which indicates that irrigation is not the only source of suspended matter in the Boise River.

Treating Boise Valley Return Flows

The Corps of Engineers has studied the cost of treating drain water in the Boise Valley (Corps of Engineers, 1976). Costs have been reported for treating 13 major drains in the valley. The costs of the three levels of treatment considered are summarized in Table 79.

Based on the costs given in Table 79, sediment ponds apparently pose the only realistic alternative. According to the Corps of Engineers' report, the pond system will not meet zero discharge standards for all constituents. The anticipated performance of the sediment pond system is shown in Table 80. The annual cost of this system was estimated at $17.50 per hectare. However, it is open to question as to whether or not the results would be worth the costs. It might be more effective to control the surface runoff from individual fields rather than wait until the water is in the drains. In any event, the ultimate treatment system (filtration-ion exchange) considered by the Corps of Engineers is completely unreasonable from the standpoint of annual costs.

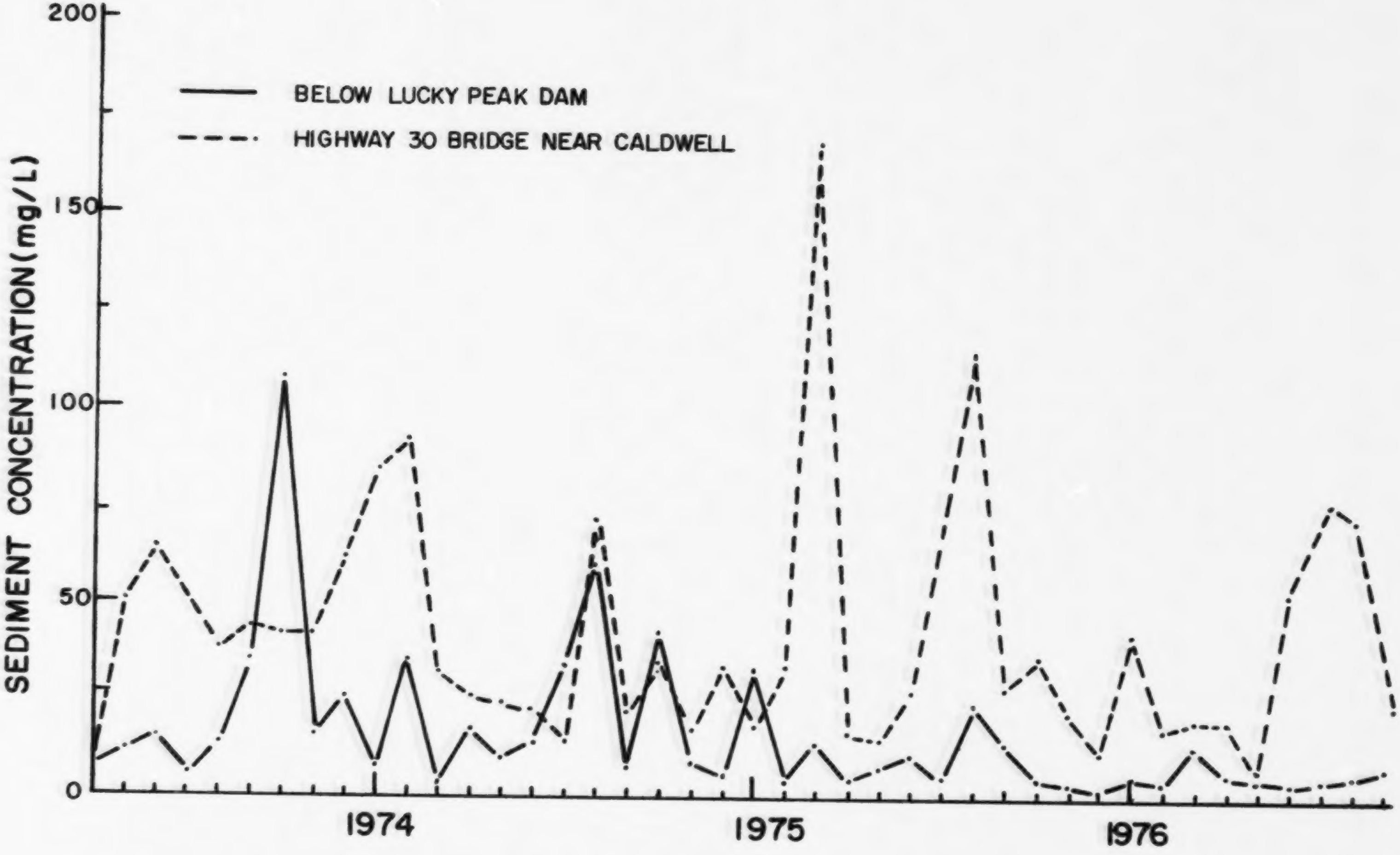

Figure 50. Sediment concentrations in the Boise River below Lucky Peak Dam and near Caldwell, April 1973 to September 1976.

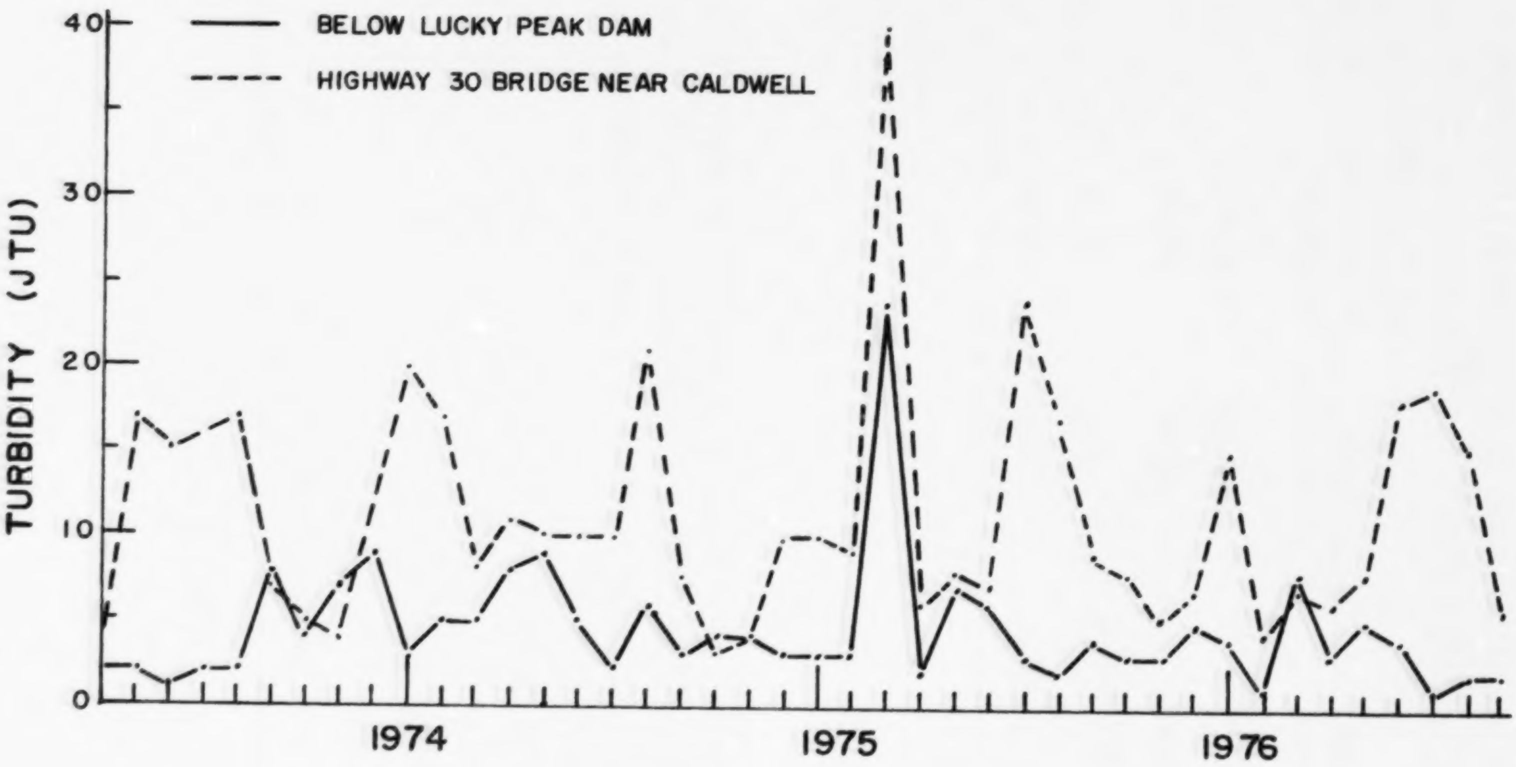

Figure 51. Turbidity readings taken in the Boise River below Lucky Peak Dam and near Caldwell, April 1973 to September 1976.

TABLE 79. COST OF TREATING RETURN FLOWS IN THIRTEEN MAJOR DRAINS IN THE BOISE VALLEY (Corps of Engineers, 1976)

	Type of Treatment		
Cost of Items	Sediment Ponds	Flocculation-Sedimentation	Filtration-Ion Exchange
Capital Investment	$1,500,000	$67,000,000	$620,000,000
Annual Operation and Maintenance	190,000	6,700,000	46,000,000
Capital Cost ($/ha)	15.00	642.00	5,930.00
Operation and Maintenance Cost ($/ha)	2.50	64.00	445.00
Total Annual Cost ($/ha)	17.50	706.00	6,375.00

TABLE 80. ANTICIPATED PERFORMANCE OF SEDIMENT POND TREATMENT SYSTEM FOR BOISE VALLEY DRAINS (Corps of Engineers, 1976)

Water Quality Improvement	Percent Removal
Suspended Solids	50 - 75
Turbidity	70
BOD	35
COD	60
Nutrients	40
Total Dissolved Solids	0

IMPACT OF SEDIMENT LOSSES

In the Boise Valley, sediment from surface-irrigated fields may be deposited in canals and drain ditches in the area or in the Boise River itself. When canals and ditches receive large amounts of sediment, costs may be incurred to remove and transport the sediment to keep the canals and ditches operational. These costs are usually incurred by downstream farms who use return flows for irrigation, irrigation districts and whoever maintains the drainage systems. When fertile soil is washed from fields, both the landowner and society suffers a loss in terms of future agricultural production. Consequently, it is preferable to prevent erosion where it initially occurs.

Farm Ditch Maintenance Costs

Data on farm production costs were collected from 93 irrigated farms in southern Idaho in the fall of 1975. Eighty-six of these farms had equipment which was used for removing sediment from ditches and for spraying and burning weeds growing on ditch banks. As shown in Table 81, the costs associated with performing these operations varied from $9.99 per hectare for 130-hectare farms to $11.74 per hectare for 57-hectare farms. Higher costs would be incurred by farmers, such as those in the lower parts of the Boise Valley, using return flows which carry large quantities of sediment for irrigation.

Irrigation District Ditch Maintenance

Several organized irrigation districts in the Boise Valley supply water from the Boise River to farmers in the area. These districts are managed by the Boise Board of Control with offices in Boise. The Board of Control manages the water distribution for 67,585 hectares of irrigated land in the Valley. Independent irrigation districts manage the distribution for the rest of the irrigated land in the area (about 59,500 hectares). In 1975, the operation and maintenance costs of the Boise Board of Control were about $24.00 per hectare or $2.20 per thousand cubic meters of water delivered. These costs include costs for maintaining and cleaning canals and ditches in the Valley in addition to costs for operating the water distribution system. The Board of Control reported that considerable sediment enters their water distribution and drainage systems from grazing lands above the Valley and from sprinkler-irrigated lands in the Dry Lake area south of Nampa. The costs of ditch and canal maintenance for the Board of Control have been estimated to be from $8.03 to $9.88 per hectare depending on the seriousness of erosion in any one year.

Assuming a farmer cost of $11.74 per hectare and an irrigation district cost of $8.03 per hectare, approximately $1,336,155 ($19.74/ha times 67,585 ha) is being spent each year in the area managed by the Boise Board of Control to clean and maintain ditches and canals. Controlling sediment losses to a greater extent would help reduce these costs.

IMPACTS OF NUTRIENTS AND OTHER POLLUTANTS

Not all of the pollution in the Boise River is due to irrigation. Other sources include urban areas, industries and livestock operations. Even

TABLE 81. ON-FARM DITCH MAINTENANCE COSTS, 1975[1]

	Costs ($/ha)	
	57-Hectare Farm	130-Hectare Farm
Ditching-All Costs		
V-Ditcher[2]	$\frac{\$58.50}{57} = 1.03$	$\frac{\$58.50}{130} = 0.45$
Tractor[3]	0.62	0.62
Labor (0.49 hr x 3.00/hr)	1.47	1.47
Total	3.12	2.54
Burning and Spraying-All Costs		
Machinery (burner and sprayer)[2]	$\frac{2\text{x}\$58.50}{57} = 2.07$	$\frac{2\text{x}\$58.50}{130} = 0.90$
Tractor	0.62	0.62
Labor and Maintenance (0.3 hr x 3.00/hr)	2.22	2.22
Materials (fuel and spray)	3.71	3.71
Total	8.62	7.45
Total Maintenance Cost	11.74	9.99

[1] Equipment costs - equipment includes a V-ditcher, weed burner and sprayer. Each costs about $600 new, has a 20-year life and a salvage value of about $60.

[2] Fixed costs - depreciation ($540 ÷ 20) plus interest of investment (0.08 x $330) plus annual repair cost ($5.00) = $58.40 for each piece of equipment (V-ditcher, burner and sprayer)

[3] Tractor and fuel costs - fixed costs for tractors, weed burners and sprayers are allocated to their major uses (crop production). A very small portion of their use is for ditch maintenance.

Ditching: 0.66 l/hr x 0.49 hr/ha = 0.33 l/ha

Burning and Spraying: 0.53 l/hr x 0.62 hr/ha = 0.33 l/ha

The fuel cost (with gasoline @ $1.89/l) = $0.62/ha for ditching and for burning and spraying.

flooding of pasture lands contributes to the overall problem. The water quality status of the Boise River and two area drains is summarized in Table 82. In the reach of the river above the irrigation drains (above Middleton), bacteria and turbidity are problems. Below this reach, temperature, dissolved oxygen and aesthetics are also problems. Bacteria, turbidity, nutrients, dissolved oxygen and aesthetics are local problems in the Ten Mile, Five Mile and Indian Creek drains. Irrigation return flows probably contribute to the temperature, nutrient, bacteria and turbidity problems in the river and the drains.

TABLE 82. BOISE VALLEY STREAM SEGMENT STATUS RELATIVE TO WATER QUALITY, 1975 (Idaho Department of Health and Welfare, 1975)

Segment Description	Water Quality Standard Problems	Stream Classification	Status
Boise River - Lucky Peak to Middleton	Bacteria, occasional turbidity	A[1]	WQL[2]
Boise River-Middleton to mouth	Bacteria, turbidity, temperature, dissolved oxygen and aesthetics	A	WQL
Ten Mile and Five Mile Creeks - source to mouth	Bacteria, nutrients and aesthetics	A	WQL
Indian Creek - source to mouth	Bacteria and occasional turbidity	A	WQL

[1] Class A - primary contact recreational waters are for uses where the human body may come in direct contact with the raw water to the point of complete submergence

[2] WQL - water quality limiting

In all of the areas shown in Table 82, water quality is limiting. In other words, water quality limiting (WQL) refers to any segment of a stream where it is known that water quality does not meet applicable water quality standards even after the application of effluent limitations required by regulatory agencies. Evidently the pollution problems of the Boise River are not going to be solved by current legislation and the problems will continue, even after some control measures are implemented, with present standards. A comprehensive water management plan may be needed for all competing water uses in the Boise Valley.

Pesticides

Although not caused by irrigation per se, pesticide contamination may be spread by surface irrigation return flows, especially in intensively cropped areas. Bodhaine (1966) observed that about seven pounds of pesticide, chiefly dieldrin and lindane, passed the Notus station each day during the latter part of July, 1965.

A paper on the quality of water in the upper middle Snake River indicates that the pesticide problem in the Boise River still existed in 1974 (EPA, 1975). In this paper, it is indicated that the highest pesticide level was in the Boise River west of Parma. Data from this study indicated a substantial input of DDT into the area between Boise and Notus. It appears that pesticides are still a problem in the Boise River and that they will continue to be a problem as long as pesticides are used and surface return flows occur. Return flows will have to be reduced or eliminated in order to reduce pesticide levels in the river and still gain the benefits of their use. Again, this could be accomplished by the introduction of water management programs which would reduce water use for irrigation and consequently reduce or eliminate surface return flows. Sprinkler irrigation or much more closely managed surface irrigation could help solve the problem.

Brownlee Reservoir

In the paper on the quality of water in the upper Snake River (EPA, 1975), it was stated that:

> The reservoir behind Brownlee Dam stores waters of the Snake River which come partially from the Boise River. By the time the Snake River leaves Brownlee Dam, it is a river of high nutrient and pesticide levels and has a low dissolved oxygen content. The station with the highest pesticide level was the Boise River west of Parma. The dissolved oxygen standards are violated at Brownlee Dam throughout most of the year. The main problem areas of the upper Snake River are: (1) the Portneuf River, (2) the Owyhee, Malheur, Boise and Weiser Rivers and (3) the Milner Reach.

It was noted that, in comparison to the other tributaries and reaches of the Snake River, the Boise River had the highest levels of phosphorus, nitrogen and pesticides. Obviously the Boise River is not the only contributor to problems in the Snake River, although it is probably a major contributor in the Brownlee Reservoir area. What additional impacts the Boise River itself has on downstream water users is unknown. No evidence has been found to indicate direct economic losses. Where pollution problems from irrigation are concerned, it is probably best to control pollutant inputs at the sources of the problem rather than at downstream locations. It would seem that improving on-farm management practices to reduce sediment losses and the introduction of nutrients, pesticides and other chemicals into return flows would be the best approach to solving these problems.

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